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Volume I

Draft Programmatic
Environmental Impact Statement

October 1999

Transportable Treatment Systems for Non-Stockpile Chemical Warfare Materiel

U.S. Department of the Army
Project Manager for Non-Stockpile Chemical Materiel
Aberdeen Proving Ground, Maryland

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PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

TRANSPORTABLE TREATMENT SYSTEMS FOR NON-STOCKPILE CHEMICAL WARFARE MATERIEL

Lead Agency: Department of the Army Program Manager for Chemical Demilitarization

Cooperating Organizations
Defense Logistics Agency
U.S. Air Force
U.S. Navy
U.S. Marine Corps
U.S. Army Corps of Engineers
U.S. Army Environmental Center

Consulting Organizations
U.S. Environmental Protection Agency, Office of Federal Activities
U. S. Environmental Protection Agency, Office of Solid Waste, Permits Branch
Centers for Disease Control and Prevention, National Center for Environmental Health
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PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

TRANSPORTABLE TREATMENT SYSTEMS FOR NON-STOCKPILE CHEMICAL WARFARE MATERIEL

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PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

TRANSPORTABLE TREATMENT SYSTEMS FOR NON-STOCKPILE CHEMICAL WARFARE MATERIEL

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LEAD AGENCY: U.S. Department of the Army, Product Manager for Non-Stockpile Chemical Materiel

COOPERATING AGENCIES: U.S. Department of the Air Force, U.S. Department of the Navy, U.S. Marine Corps, Defense Logistics Agency, U.S. Army Corps of Engineers, U.S. Army Environmental Center

TITLE OF PROPOSED ACTION: To complete development and testing of four types of transportable treatment systems for non-stockpile chemical warfare materiel and make them available for deployment as required.

POINT OF CONTACT: Information concerning this environmental impact statement can be obtained by calling 1-800-488-0648, or by writing to the Product Manager for Non-Stockpile Chemical Materiel, ATTN: SFAE-CD-NP (Mr. John Gieseking/PEIS), Aberdeen Proving Ground, MD 21010-5401

APPROVAL AUTHORITY: U.S. Department of the Army, Deputy Assistant Secretary for Environment, Safety, and Occupational Health

DOCUMENT DESIGNATION: Draft Programmatic Environmental Impact Statement (PEIS)

AFFECTED JURISDICTION: Nationwide

ABSTRACT: The U.S. Army's Product Manager for Non-Stockpile Chemical Materiel is responsible for destroying certain types of chemical warfare materiel (CWM) called non-stockpile CWM. Non-stockpile CWM is all CWM that is not part of the United States' unitary stockpile of CWM (called stockpile CWM). This non-stockpile CWM must be destroyed in order to protect human health and safety, comply with an international treaty referred to as the Chemical Weapons Convention, and carry out the requirements of the U.S. Congress. Non-stockpile CWM comprises a variety of munitions, containers, equipment, and facilities. However, only those non-stockpile CWM items that are munitions, containers, or chemical agent identification sets are considered in this Draft PEIS (destroying the other non-stockpile CWM is addressed in other documentation under the National Environmental Policy Act). The CWM items considered in this Draft PEIS are currently stored at military installations or may be recovered in the future from burial sites or test and firing ranges. The Army is developing four types of transportable chemical treatment systems that can be used to treat these CWM items. The Army must now decide whether to complete the development of the treatment systems so that they can be available for field use to treat CWM items. In compliance with the National Environmental Policy Act and Army Regulation 200-2, Environmental Effects of Army Actions, the Army has prepared this Draft PEIS to evaluate the environmental impacts of completing these systems and making them available for deployment. Two alternatives are analyzed in detail in the Draft PEIS. Under the preferred alternative, the Army would complete development of all four transportable treatment systems and make them available as required for use at sites to treat and process non-stockpile CWM. Under the no-action alternative, the Army would suspend or discontinue development of the four proposed treatment systems and continue research and development on other treatment technologies, methods, and processes until another type of treatment system is developed. The Draft PEIS describes the possible environmental and socioeconomic impacts of the consequences of selecting either of these alternative actions. This Draft PEIS is programmatic in nature to support the programmatic decision to be made regarding the four treatment systems. No decisions are being made at this time about deploying treatment systems to specific sites.

COMMENTS: Comments on this Draft PEIS should be provided within 90 days of the publication of the Notice of Availability in the Federal Register by the U.S. Environmental Protection Agency to ensure consideration in preparing the Final PEIS. Comments should be made by calling the phone number above or by sending written comments to the Point of Contact identified above. Public meetings to solicit comments will be held at locations and dates to be announced separately.

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Executive Summary

The Army must destroy various types of chemical warfare materiel (CWM) that are currently stored at military installations or that will be recovered in the future from burial sites or test and firing ranges throughout the United States and its territories. This CWM is called non-stockpile CWM. Non-stockpile CWM comprises those CWM items that are not part of the current U.S. stockpile of chemical munitions (referred to as stockpile CWM) stored at eight locations in the United States and on Johnston Island in the Pacific Ocean. The Army must destroy both the non-stockpile and stockpile CWM to ensure protection of public health and safety and the environment from the hazardous materials contained in the CWM, to comply with an international treaty that requires its destruction, and to comply with federal legislation.

Non-stockpile CWM comprises a wide variety of munitions, containers, equipment, and facilities. However, this environmental impact statement is concerned with only a portion of this materiel: non-stockpile chemical munitions, containers of chemicals that are not munitions, and chemical agent identification sets (CAIS). These items are currently buried at a number of locations in the United States and its territories and possessions or are in storage at military installations.

The U.S. Army is the designated Department of Defense (DoD) Executive Agent for destroying CWM. The Army has implemented the Non-Stockpile Chemical Materiel Project (NSCMP) to develop safe methods and systems to destroy non-stockpile CWM. The NSCMP is responsible for processing and treating non-stockpile CWM . Other DoD organizations are responsible for managing and remediating CWM burial sites and managing stored CWM.

An important part of the NSCMP's mission is to develop transportable systems that can be moved from one location to another to treat non-stockpile chemical munitions, containers of chemical agents other than munitions, and CAIS. Research and development on four such treatment systems has reached the point of maturity that compels the Army to decide whether it wants to complete the development of the systems and make these systems available for deployment in the field.

The action proposed by the Army and analyzed in this environmental impact statement is to complete the development and testing of all four transportable treatment systems so that they would be available to be used in the future where needed and appropriate to treat and process stored non-stockpile CWM and non-stockpile CWM recovered from burial sites and test and firing ranges. The Army would also continue to assess and evaluate the treatment potential of other technologies, methods, and processes.

This environmental impact statement has been prepared under the requirements of the National Environmental Policy Act; the Code of Federal Regulations, Title 40, Parts 1500-1508; Army Regulation 200-2; and Executive Orders. The purpose of the document is to

provide Army decision-makers with information on the possible environmental consequences of the proposed Army action and alternatives to it.

Need for and Purpose of the Action

The Army needs to destroy non-stockpile CWM to protect human health and safety and the environment, to comply with an international treaty, and to execute the requirements of the U.S. Congress. CWM is a threat to human health and safety because of the hazardous nature of its chemical contents. At a burial site, these chemicals could leak into the environment or be accidentally released during ground-disturbing activities that breach CWM items. At a storage site, a release could be caused by an external event such as a tornado or airplane crash into the storage building. CWM must also be destroyed because the United States has ratified the *Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction*, commonly referred to as the Chemical Weapons Convention. The Convention requires that CWM be destroyed within a specified period of time. The U.S. Congress has also required the Army to prepare a plan for destroying non-stockpile CWM.

The purpose of the proposed Army action is to make available safe and cost-effective transportable treatment capability that can treat or repackage chemicals in non-stockpile CWM items and produce waste products that can be handled and disposed of within the existing commercial hazardous waste treatment and disposal system in the United States. There are currently 168 sites at which non-stockpile CWM is believed to be buried, suspected to be buried, or currently stored. Most of these sites are known to have or are suspected of having only a few items or a small quantity of CWM. Because of this, the Army has determined that it is not feasible to design and construct fixed processing and treatment facilities at all of these locations. Therefore, the Army has developed transportable systems that can be moved to a number of locations to carry out the mission to process and treat this non-stockpile CWM.

Scope of Environmental Review

This environmental impact statement is programmatic in nature because the Army is only deciding at this time whether the four transportable treatment systems currently undergoing final development and testing should be completed so that they would be available for field deployment. The Army is not deciding how and where these systems would be deployed to treat and process items at specific CWM burial or storage site. These would be site-specific decisions that would be made separately in the future for each location only after additional environmental review, public involvement, and consultation with the appropriate federal, tribal, state, and local authorities.

Non-Stockpile Chemical Warfare Materiel Considered in this Environmental Impact Statement

The kinds of non-stockpile CWM considered in this environmental impact statement are chemical munitions, chemical containers that are not munitions, and CAIS. Chemical munitions were designed to disperse chemical warfare agents or industrial chemicals (usually using an explosive charge) onto an enemy target either in the form of a liquid aerosol, an unburned residue, or a gas. Chemical containers are items that are not munitions but contain chemical agent or industrial chemicals. These include glass ampoules and bottles, drums, and containers of various sizes up to a one-ton container meeting U.S. Department of Transportation specifications for shipping hazardous materials. CAIS were used by the military to train soldiers to identify chemical agents in the field. The chemical agent in CAIS is contained in ampoules or bottles in small quantities. These types of CWM items are currently in storage at military installations or buried at sites throughout the United States and its territories.

Responsibilities for Buried and Stored Non-Stockpile Chemical Warfare Materiel

The responsibility for managing, processing, and treating buried and recovered CWM is divided among several DoD organizations. In general, managing CWM burial sites and stored (recovered) CWM is the responsibility of the military command for sites on active military installations or the U.S. Army Corps of Engineers for sites on property no longer owned by DoD. The NSCMP is responsible for processing and treating CWM after the decision has been made that items in burial sites or storage must be destroyed and the items are brought to a treatment system site for processing.

Transportable Treatment Systems

The Army is developing four types of integrated transportable treatment systems for non-stockpile chemical materiel. These are briefly described in Table ES- 1.

Each transportable treatment system would use a chemical neutralization process as the means of treating chemical warfare agents and sometimes the industrial chemical phosgene. Chemical agent would be mixed with other chemicals—called treatment reagents—that convert the chemical agent into waste chemical compounds, called neutralent wastes. The neutralent wastes would be much less hazardous than chemical agents and could be handled and disposed of like similar hazardous chemical wastes that result from regular industrial processes. These treatment wastes would be sent to commercial treatment, storage, and disposal facilities (TSDFs) that specialize in industrial hazardous waste treatment. The facilities would carry out additional treatment of the wastes and dispose of the residue in accordance with the Resource Conservation and Recovery Act (RCRA) and other federal and state regulations.

Table ES-1. Transportable Treatment Systems

System	Type of Non-Stockpile Chemical Materiel Treated	Status
Rapid Response System (RRS)	Chemical agent identification sets	Full-scale prototype designed and assembled
Munitions Management Device–Version One (MMD-1)	Non-stockpile chemical munitions without explosive components Small containers of chemical agent Chemical samples	Full-scale prototype designed and assembled
Munitions Management Device–Version Two (MMD-2)	Non-stockpile chemical munitions with explosive components that are safe to handle and transport Bulk items up to large bombs and one-ton containers using bulk item accessing equipment	Full-scale prototype in design; explosive containment chamber tested
Explosive Destruction System (EDS)	Chemical munitions with explosive components that are not safe to handle or transport Chemical munitions, with or without explosive components	EDS Phase I prototype in testing. EDS Phase II model in design.

Industrial chemicals would be removed from the munitions or original containers and repackaged in new containers that meet regulatory requirements for shipping. The containers would be transported to a commercial TSDF for final treatment and disposal.

Alternatives Considered

The Army has considered a number of ways that non-stockpile CWM could be processed and treated to meet the NSCMP mission requirements and comply with the Chemical Weapons Convention. These are described in Table ES-2. The preferred alternative and the no-action alternative are analyzed in detail in this environ mental impact statement. The Army has determined that the other alternatives would not meet the NSCMP mission requirements or could not be feasibly implemented at this time. Therefore, these alternatives, which involve using the transportable treatment systems with conditions or using technologies or facilities other than the transportable treatment systems, are not analyzed in this environmental impact statement.

Table ES-2. Alternatives Considered for Analysis

Use Transportable Treatment Systems (Preferred Alternative)[a]	
Use transportable treatment systems	Complete development and testing of all four transportable treatment systems described in Section 2 and Appendix C and make them available to be used where needed and appropriate to treat and process non-stockpile CWM. Continue to assess and evaluate the treatment potential of other technologies, methods, and processes.
Use the Transportable Treatment Systems with Conditions[b]	
Store neutralent and other wastes that require thermal treatment	Store neutralent and other wastes from the transportable treatment systems that require combustion as the final treatment method to meet the RCRA land disposal restrictions. Treat these wastes in the future when some method other than combustion is available that meets the RCRA land disposal restrictions.
Restrict the Operating Location of the Treatment Systems	Decide programmatically to restrict deployment of the transportable treatment systems only to locations on the military installation or other property where the CWM items are stored or are being recovered from burial sites or test and firing ranges.
Use Technologies or Facilities Other than the Transportable TreatmentSystems[b]	
Use stockpile disposal facilities	Use facilities to be used or proposed for use to destroy the national stockpile of chemical weapons.
Use other treatment methods	Use some other treatment technology, method, or process than those used in the preferred alternative.
Use commercial treatment facilities	Send non-stockpile CWM to commercial facilities with permits to handle, treat, and dispose of hazardous materials.
Build fixed facilities at storage, burial, and recovery sites	Design and construct fixed treatment and processing facilities at locations where non-stockpile CWM is stored, buried, or recovered.
No-Action Alternative[a]	
Take no action at this time, and develop and deploy some other treatment system in the future	Suspend or discontinue developing the transportable treatment systems of the preferred alternative. Continue research and development on other treatment technologies, methods, and processes. When a suitable treatment technology, method, or process is developed into a transportable or other suitable system, make the system available for deployment after appropriate environmental, safety, and other reviews.

[a]Analyzed in detail in this environmental impact statement.
[b]Not considered further in this environmental impact statement.

CWM – Chemical warfare materiel
RCRA – Resource Conservation and Recovery Act

Preferred Alternative

The preferred alternative is to complete development of the four transportable treatment systems so that they would be available for deployment in the field with appropriate support equipment, facilities, and personnel as required to treat non-stockpile CWM. The type of CWM that is present at a specific site would determine the type or types of treatment systems that would be deployed. The Army would continue to review and assess the CWM treatment potential of other technologies, methods, and processes and would also continue to review and assess other methods and technologies for treating neutralent wastes. As methods appear feasible in the future, the Army would determine their suitability within adequate health, safety, and environmental protection requirements.

If the Army implements the preferred alternative, transportable treatment systems would be available to be deployed as needed to locations to process and treat CWM currently in storage or recovered from burial sites or test and firing ranges. Chemical warfare agents would be treated with chemical reagents as described above, and the wastes would be shipped to a commercial TSDF for handling and disposal like other industrial hazardous wastes. Industrial chemicals would be repackaged without treatment (except phosgene in some instances) and shipped to a TSDF for treatment and disposal. The Army would consider the operating and compliance history of a TSDF when selecting the facility to receive treatment wastes and would continue to audit the compliance performance of the TSDF while treatment wastes are being processed and disposed of.

The transportable treatment systems would be deployed to a location determined to be most suitable for processing and treating CWM recovered or stored at a specific location. The treatment site location could be located on the military installation or other property where the CWM items are stored or buried or on a location elsewhere. The stored or recovered CWM items would be moved by truck on local roads if the treatment site were near the recovery or storage location. If the treatment site were distant from the recovery or storage location, the Army would use military aircraft for part or all of the transportation to the treatment site.

Laws restrict where non-stockpile CWM can be moved to if the treatment location is distant from the burial or storage site. CWM cannot be moved outside of the state in which it is stored or recovered unless it is being moved to the nearest CWM stockpile storage facility that has a permit to receive and store the CWM. The Army would consult with federal, tribal, state, and local authorities as appropriate before moving CWM.

The future decision as to where to deploy transportable treatment systems would be a site-specific one. The decision would be based on the specific characteristics of the location where the CWM to be treated is stored or recovered. Public input and comment and additional environmental and safety review would be part of the deployment decision process.

No-Action Alternative

If the no-action alternative is selected, the Army would suspend or discontinue developing the transportable chemical treatment systems described in the preferred alternative, and these systems would not be made available for deployment to treat non-stockpile CWM. The Army would continue research and development on other non-stockpile CWM treatment technologies and methods. When a suitable treatment technology or method were developed into a transportable or other suitable system, the system would be made available to be deployed to treat recovered non-stockpile CWM.

As a consequence of discontinuing development of the current transportable chemical treatment systems, the DoD would continue the current program for handling non-stockpile CWM at burial sites, recovery locations, or currently in storage. Burial sites would continue to be managed to protect public health and safety and the environment under ongoing military installation or U.S. Army Corps of Engineers programs, as appropriate. CWM currently being stored would continue to be stored, monitored, and maintained. Any non-stockpile CWM recovered in the future from burial sites or test and firing ranges would be stored, monitored, and maintained at the recovery location if site characteristics allow it, or it would be transported to a suitable storage location elsewhere subject to the constraints on CWM movement discussed above for the preferred alternative. When a suitable treatment system is developed in the future, it would be made available for deployment after additional safety, environmental, and other appropriate reviews.

Implementing the no-action alternative would not relieve the United States of the requirement to destroy stored or recovered non-stockpile CWM in order to protect human health and safety and the environment or to comply with the provisions of the Chemical Weapons Convention. If the Army could not develop a new CWM treatment method in a timely manner, it is possible that the United States could not meet the original timelines for destroying CWM in the Chemical Weapons Convention and may have to request an extension of the deadlines.

Environmental Consequences

The environmental consequences of the preferred alternative and the no-action alternative are summarized in Tables ES-6 and ES-7 (located at the end of this executive summary). Many of the environmental consequences of deploying and operating the transportable treatment systems would be site-specific and would depend on the particular characteristics of the operating site. In general, there would not likely be significant environmental consequences from normal operation of the transportable treatment systems. An accidental release of chemical agent or industrial chemicals could result in short-term environmental and human health impacts. Under the no-action alternative, the impacts of treating the stored and recovered CWM in the future cannot be determined at this time because the type of treatment that might be used is not yet known.

Preferred Alternative

If the preferred alternative were selected, environmental impacts would be possible from normal operations at a treatment site and the associated transport of CWM items, treatment wastes, and treatment chemicals; and from the accidental release of hazardous substances to the environment.

Normal Operations

Normal operation of the transportable treatment systems means that all activities at an operating site would take place as planned and designed within engineering controls and without any accidental releases of hazardous chemicals such as chemical agent or treatment wastes. All associated activities, such as transport of CWM, chemicals, and waste and all treatment and disposal activities at the TSDF that receives the operation wastes, also take place as planned, designed, or within regulatory limits.

Operating at a site would disturb from one to six acres of land, depending on the number and types of treatment systems operating at a site. Access to economically important minerals under or near the site could be restricted or eliminated for the duration of site activities. Operation of diesel generators for site emergency or operating power could require an air quality review and permitting depending on site-specific features such as the air quality status of the site. No hazardous air pollutants would be emitted from the operating systems because of the filter systems incorporated into the design of the treatment systems. Ecological impacts would depend on the characteristics of the operating site and surrounding land. There could be some land use or economic impacts if the use of adjacent and nearby property is restricted for safety reasons during the period of operation. Environmental justice issues would be site-specific and would have to be considered in the site-selection process.

Accidental Release of Hazardous Substances

Hazardous substances could be released accidentally to the environment during activities at a treatment site or associated transportation operations, although the risk of such releases is very small. These substances could include chemical warfare agents and industrial chemicals in the CWM items that would be treated and processed, chemicals used in the treatment process, liquid neutralent wastes produced from treating CWM items, and fuel oil or other petroleum products used at a treatment site or in transportation activities. Hazardous substances could be accidentally released at the treatment site, while transporting CWM items or treatment wastes, or at the TSDF that receives the wastes for final treatment and disposal.

Risk of Accidental Release. An accident risk assessment has been performed for the accidental release of chemical agent, industrial chemicals, and treatment wastes. Since no specific sites have been analyzed, the analysis was based on generic assumptions about site activities (called unit operations) that would take place if the treatment systems were deployed. The purpose of the accident risk assessment was to identify potential risks to the general public. Risk is a combination of accident frequency and the consequence of the accident.

In general, the risks associated with accidental releases from most of the unit operations considered fall in the lower to intermediate risk group categories (Table s ES-3 and ES-4). As to be expected, risk associated with the handling and treatment of CWM items with explosive components would be greater than those that do not have explosives. Risk associated with accidental releases from explosive detonations is also influenced by the size of the controlled area (i.e., area restricted from members of the general public). A larger controlled area would be necessary to keep risk the lowest. Risks associated with the transport of CWM items by aircraft would also be greater, primarily because a controlled area could not be predetermined for such accidents.

Risk from accidental release of industrial chemicals (Table ES-4) during transport to a commercial facility also falls in the lower to intermediate risk group categories. Risks associated with transporting treatment wastes are in the intermediate risk group for all treatment systems. However, the risk would be influenced more by the frequency of the transportation accidents and not by the severity of the release (i.e., health consequence as a result of exposure to chemical constituents).

Effects on the Natural Environment. The downwind natural environment could suffer acute affects if chemical agent or industrial chemicals were released into the air explosively or evaporatively at a treatment site or in a transportation accident. Death or injury to plants and animals could occur in the area of the plume if concentrations were great enough. Such an event would be a one-time occurrence that would affect a small area. The magnitude of the impact would be site-specific, but it is unlikely that a release would greatly affect regional populations of organisms. Long-term impacts from residual chemicals in the environment would be unlikely because of the Army cleanup response to a release and because chemical agents would break down quickly in the environment into other products that would be much less hazardous, would not be persistent, and would not bioaccumulate in the food web. Arsenic in Lewisite would be long-lived in the environment unless cleaned up.

Spills of treatment chemicals and treatment wastes would be hazardous only at the site of the spill because of low volatility and would not likely expose the natural environment. Chloroform wastes would be volatile, but the maximum quantity that could be spilled would result in a small area of effect.

The threat to aquatic systems from a spill of diesel fuel used for generators at a treatment site would be site-specific. Site-selection and site-operating planning would minimize or eliminate the potential for environmental impact. Spills of hydraulic fluids and lubricants would not likely have significant effects because of the small quantity present at a site and the standing operating procedures in place to respond to and clean up these spills.

Effects on Human Health and Safety. Accidental releases of chemical warfare agents have the potential to cause injury and death if the release results in exposure. Airborne chemical warfare agents and the breakdown products EA 2192, 2 -chlorovinyl arsenous acid,

Table ES-3. Summary of Risk Group Assignments for Unit Operations for Chemical Agent

Controlled Area for Treatment System (meters)	Unit Operation					
	At Treatment Site				Transport to Treatment Location	
	Interim Storage in Portable Buildings	Transport and Handling[a]	Treatment		Transport and Handling[b]	Air Transport
Site-Type B, CAIS Only (CAIS with Mustard [HD])						
			RRS			
200	❍	❍	❍		❍	❍
1,000	❍	❍	❍		❍	
2,000	❍	❍	❍		❍	
Site-Type C, Non-Explosive Munitions (M70 bombs with Mustard[HD])						
			MMD-1			
200	□	□	□		□	□
1,000	□	□	❍		□	
2,000	❍	□	❍		□	
Site-Type E, Explosive Munitions (155-mm projectiles with Mustard [HD])						
			MMD-2	EDS		
200	□	□	□	□	□	
1,000	□	□	❍	□	□	
2,000	❍	□	❍	□	□	
Site-Type F, Explosive Munitions (155-mm projectiles with Sarin [GB])						
			MMD-2	EDS		
200	□	□	□		□	
1,000	□	□	□		□	
2,000	□	□	□	□	□	
Site-Type G, Chemical Samples (Ton container with Sarin [GB])						
			MMD-2			
200	□	□	□		□	□
1,000	□	□	□		□	
2,000	□	□	□		□	
Site-Type H, Unsafe Munition (155-mm projectile with Sarin [GB])[c]						
			EDS			
200	NA	NA			NA	NA
1,000	NA	NA			NA	
2,000	NA	NA	□		NA	

– upper risk group □ – intermediate risk group ❍ – lower risk group

[a] Transportation and handling between interim storage facility and treatment system.
[b] Transportation and handling between interim storage facility and military airfield by truck, and between destination military airfield and storage facility.
[c] Analyzed only for the treatment unit operation using the EDS. Munition unsafe to move to an MMD-2.

CAIS – chemical agent identification set
EDS – Explosive Destruction System
mm – millimeter
MMD-1 – Munitions Management Device–Version One
MMD-2 – Munitions Management Device–Version Two
NA – not applicable

Table ES-4. Summary of Risk Group Assignments for Unit Operations for Industrial Chemicals

Controlled Area for Treatment System (meters)	Unit Operation				
	At Treatment Site			Transport to Treatment Location	
	Interim Storage in Portable Buildings	Transport and Handling[a]	Treatment	Transport and Handling[b]	Air Transport
Site-Type A, CAIS Repackaged Only (CAIS with Phosgene)					
			RRS		
200	□	❍	❍	□	❍
1,000	❍	❍	❍	□	
2,000	❍	❍	❍	□	
Site Type D, Non-Explosive Munitions (M78 bombs with Phosgene)					
			MMD-2		
200	□	□	□	□	□
1,000	□	❍	□	❍	
2,000	□	❍	□	❍	

– upper risk group □ – intermediate risk group ❍ – lower risk group

[a] Transportation and handling between interim storage facility and treatment system.

[b] Transportation and handling between interim storage facility and military airfield by truck, and between destination military airfield and storage facility.

CAIS – chemical agent identification set

MMD-2 – Munitions Management Device–Version Two

RRS – Rapid Response System

and inorganic arsenic represent the principal acute threats from accidental release. Chemical warfare agents are short-lived substances that are unlikely to represent chronic threats. However, the breakdown products inorganic arsenic, 2-chlorovinyl arsenous acid, and EA 2192 have the potential to present chronic threats.

Accidental releases of industrial chemicals, treatment chemicals, and neutralent waste chemicals have the potential to cause injury primarily through their irritant and/or incapacitating properties, although some can be lethal at high concentrations. The likelihood of exposure to the volatile chemicals—such as phosgene, chloroform, and t-butyl alcohol—would be higher than for the other chemicals. However, these chemicals are generally not persistent in air, and any exposure that might occur would be limited by their rapid dissipation and environmental degradation to form relatively innocuous breakdown products at most sites.

Generally, the probability of accidental release would be small, and the probability of exposure would therefore also be small. In the event of an accidental release, the probability of exposure would still be small because of the planning and review in siting of the mobile treatment facility, contingency plans developed by the Army, and other site-specific factors.

No-Action Alternative

If the no-action alternative were selected, environmental impacts would be possible from establishing long-term storage facilities for CWM items and treating these items in the future when a treatment method is available. Impacts could also occur from releasing chemical agent or industrial chemicals to the environment at the storage site or during future treatment. Implementing the no-action alternative would not relieve the Army of the requirement to destroy stored or recovered non-stockpile CWM in order to protect human health and safety and the environment or comply with the provisions of the Chemical Weapons Convention.

Normal Operations

Impacts at storage sites would be site-specific. Constructing a new storage building would likely have small to modest impacts associated with site preparation and construction of the storage building. Modifying an existing building for storage would likely have few impacts. There could be land use and economic impacts if restrictions were placed on adjacent and nearby property for safety reasons. These impacts would be less likely if storage were on an existing military installation.

The impacts of treating the CWM in the future cannot be determined at this time because the type of technology or method that could be developed is not known.

Accidental Release of Hazardous Substances

Chemical agent or industrial chemicals could be released to the environment at a storage location or during transportation of CWM to a storage location or a future treatment site. A release could occur at a storage or treatment location from a handling accident or an external event, such as an earthquake or a plane crash into the storage building, that breaches the overpacks that protect the stored CWM items. A release during transportation could occur in a truck or aircraft crash.

Risk of Release. The risks to the general public associated with an accidental release of chemical agent or industrial chemicals from storage facilities fall in the lower to intermediate risk group categories, as shown in Table ES-5. Risks would be primarily from low-frequency external events (e.g., aircraft crash) that result in large releases. The risk from transporting CWM items by truck and/or aircraft to a storage location or from a storage location to a future treatment site would be the same as for the preferred alternative since the activities involved would be the same. The risk associated with an accidental release from a future treatment system or site cannot be determined at this time because the treatment system and site requirements are not yet known. However, continued and prolonged storage would be an

Table ES-5. Summary of Risk Group Assignments for Unit Operations for Long-Term Storage

Controlled Area around Storage Area (meters)	Unit Operation			
	Long-Term On-Property Storage[a]	Long-Term Off-Property Storage[b]	Transport and Handling[c]	Air Transport[d]
Site-Type A, CAIS Only (CAIS with Phosgene)				
200	□	❍	□	❍
1,000	❍	❍	□	
2,000	❍	❍	□	
Site-Type B, CAIS Only (CAIS with Mustard [HD])				
200	❍	❍	❍	❍
1,000	❍	❍	❍	
2,000	❍	❍	❍	
Site-Type C, Non-Explosive Munitions (M70 bombs with Mustard [HD])				
200	□	❍	□	□
1,000	□	❍	□	
2,000	❍	❍	□	
Site Type D, Non-Explosive Munitions (M78 bombs with Phosgene)				
200	□	❍	□	□
1,000	□	❍	❍	
2,000	□	❍	❍	
Site-Type E, Explosive Munitions (155-mm projectiles with Mustard [HD])				
200	□	❍	□	
1,000	□	❍	□	
2,000	❍	❍	□	
Site-Type F, Explosive Munitions (155-mm projectiles withSarin [GB])				
200	□	❍	□	
1,000	□	❍	□	
2,000	□	❍	□	
Site-Type G, Chemical Samples (Ton container withSarin [GB])				
200	□	❍	□	□
1,000	□	❍	□	
2,000	□	❍	□	

– upper risk group □ – intermediate risk group ❍ – lower risk group

CAIS – chemical agent identification set

[a] Storage facility is located on the military installation or other property where t he items were recovered. Storage would be in a portable facility.

[b] Storage facility is not located on the military installation or other property where the items were recovered. Storage would be in an igloo.

[c] Transportation and handling between interim storage facility and military airfield and between destination military airfield and off-property storage facility.

[d] Controlled area designation does not apply to air transport.

additional risk not present in the preferred alternative. Furthermore, as CWM items deteriorate with age, there would also be a potential for an increase in the frequency of accidental explosive detonations during handling, transport, and treatment of CWM items with explosive components.

Ecological and Human Health Impacts. The impact of releases of chemical agents and industrial chemicals during storage or transportation to or from a storage site would be similar to those that could occur from an accidental release of these substances in the preferred alternative. The impacts of an accidental release during future treatment cannot be determined at this time because the type of treatment systems and site circumstances are not yet known.

Table ES-6. Comparison of Alternatives for Normal Operations[a]

Preferred Alternative	No Action Alternative
Air Quality	
Air emissions would be generated by various activities associated with the setup, operation, closure, and demobilization of transportable treatment systems. The types and quantities of emissions generated would be extremely site-specific. Air emissions generated would include criteria pollutants released by the operation of motor vehicles and equipment involved in site activities and in the transport of personnel, equipment, materials, and wastes. Fugitive dust would be released by vehicles, equipment, and activities that disturb the ground surface. Hazardous air pollutants could also be released by vehicles, equipment, and various construction and maintenance related activities, such as painting and solvent cleaning. The transportable treatment systems have been designed with redundant controls to prevent the release of chemical agents, treatment reagents, neutralent waste components, or other industrial chemicals into the environment during operations. Treatment and unpack systems would be placed in trailers or other environmental enclosures under negative air pressure to ensure that any gases that would be released would only be released from an exhaust stack after passing through redundant carbon filter elements. These filters would be selected to capture specific chemicals that would be treated. Near real-time monitors would be strategically located to ensure that no agent or other chemicals used in the systems would be emitted. Air quality impacts would be extremely site specific and would depend on a number of site factors. All emissions and any air quality impacts would comply with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented, as necessary, prior to the start of operations. All necessary air quality reviews, permits, and approvals would be obtained prior to setup and operation at a site. The specific reviews, permits, and approvals that would be necessary would also be determined on a site-specific basis. The need for additional controls and mitigating measures would be identified and implemented based on these reviews, permits, and approvals. The use of diesel-powered generators to supply primary power at sites where large numbers of CWM items would need to be processed could trigger the need for air quality reviews and permits at such sites, especially for MMD-2 systems.	Air emissions would be generated by various activities associated with the setup and operation of long-term storage facilities. The types and quantities of emissions generated would be extremely site-specific. Emission quantities would typically be less than those from corresponding treatment system activities. Air emissions generated would include criteria pollutants released by the operation of motor vehicles and equipment involved in site preparation and operational activities and in the transport of personnel, equipment, materials, and wastes. Fugitive dust would be released by vehicles, equipment, and activities that disturb the ground surface. Hazardous air pollutants could also be released by vehicles, equipment, and various construction and maintenance related activities, such as painting and solvent cleaning. Air quality impacts would be extremely site specific and would depend upon such factors as the specific types and quantities of air pollutants emitted by the various activities, existing air quality in the area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts would comply with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented, as necessary, prior to the start of operations. All necessary air quality reviews, permits, and approvals would be obtained before a long-term storage facility was set up and operated at a specific site. The specific reviews, permits, and approvals that would be necessary would be determined on a site-specific basis. The need for additional controls and mitigating measures would be identified and implemented based on these reviews, permits, and approvals. Air emissions and related air quality impacts from future technologies, processes, or methods that would ultimately be used to treat the CWM items in long-term storage under this alternative cannot be determined at this time since these technologies, processes, and methods are not yet known.

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Noise	
No significant adverse impacts due to noise from site operating activities are expected. Noise levels could increase during site preparation, setup, operational, and demobilization activities due to transport trucks and construction equipment ; however, noise would be of short duration and would likely occur only during normal work hours. Greatest potential impacts could occur if lack of available power requires continuous operation of electric power generators. Once operations were under way, noise impacts from commuting workers and occasional truck traffic would be minor. Use of helicopters to transport non-stockpile CWM offsite could produce additional noise that would approach a disturbance level for short periods.	Potential noise impacts during storage site preparation would be comparable to those generated by a small construction site. Noise impacts would likely occur during normal work hours and would be of limited duration. Also, because the storage sites would usually be located away from inhabited areas for safety reasons, any noise generated at the site would be attenuated by distance. There would be no significant noise impacts during the period non-stockpile CWM items were stored in the IHF or existing storage facilities. Use of helicopters to transport CWM to and from a storage location could produce noise that would approach a disturbance level for short periods. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.
Geology, Minerals, and Soils	
Site soils would be affected by grading and construction activities required for the treatment facilities and could remain affected for the duration of the treatment campaign. Primary impacts would be soil compaction and changes to soil structure, and the potential increase of soil erosion. Mitigating measures could be implemented to minimize impacts. Areas affected would range from 1 to 6 acres, depending upon the treatment systems deployed. Some additional land could be required if additional transportation facilities are needed. Access to economically important subsurface minerals would be temporarily postponed. Off-site transport of CWM for treatment would not impose any additional impacts unless new roads or transportation facilities are needed.	Soils could be affected by ground-disturbing activities necessary to prepare storage facilities for recovered CWM. Modifying existing buildings or bunkers to store CWM would likely have little or no impact on soils. The extent of impacts on soils would be determined by the characteristics of each specific site and the mitigating measures implemented at each site. The impacts would continue as long as the building remained at the location. Access to economically important subsurface minerals would be temporarily postponed. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.
Groundwater	
It is unlikely that groundwater would be affected by site activities. No wells would be drilled. Impacts to groundwater would be determined on a site-specific basis. Normal leaks of petroleum products from equipment operating at a site would be unlikely to have an impact because the volume released would be small and standing operating procedures would be in place to remove contaminated soils from the site before groundwater could be affected.	It is unlikely that activities at the storage site would have much potential to affect groundwater resources. It is unlikely that wells would be drilled at the site. Normal leaks of petroleum products from equipment operating at a site would be unlikely to have an impact because the volume released would be small and standing operating procedures would be in place to remove contaminated soils from the site before groundwater could be affected. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Ecological Environment	
Effects on the ecological environment would depend on the circumstances of each specific site and the ability to select the location of the site to reduce or eliminate adverse impacts. Areas affected at a treatment site could range from 1 to 6 acres. Off-property transport of CWM for treatment would only impose small additional impacts if new ground transportation facilities or helicopter landing pads were constructed.	Effects on the ecological environment would depend on the circumstances of each specific site and the ability to select the location of the storage site so as to reduce or eliminate adverse impacts. Off-property transport of CWM to or from a storage location would only impose small additional impacts if new ground transportation facilities or helicopter landing pads were constructed. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.
Terrestrial	
The upland environment could be affected by clearing vegetation for road construction or site preparation. Habitat on the site would be lost or reduced in ecological value while site operations take place. The extent of impact would depend upon prior habitat value, mitigating measures identified and implemented during site operations, and site restoration activities during and after site closure.	Use of an existing building for storage would likely have only minor effects on the upland environment. If a new building must be erected, the upland environment could be affected by clearing vegetation, grading, and other construction activities. The extent of these impacts would depend on the existing physical status and prior disturbance of the storage site selected.
Wetlands	
Wetlands could be affected if the site contained wetlands within the operating area or if runoff from the site affected adjacent wetlands. Adverse effects from sediment in runoff are likely to be controlled to an acceptable level or eliminated by sediment control management measures that would be required by many states and by all military installations.	It is unlikely that wetlands or floodplains would be significantly affected by storage activities because it is highly unlikely that new storage facilities would be located in these environments. If an existing storage building is used that is located in former wetlands, it is unlikely that any additional impacts would result from modifying the building for storing CWM. Sediment runoff from constructing a new storage site could also affect adjacent wetlands. Adverse effects from runoff would likely be controlled to an acceptable level or eliminated by sediment control management measures that would be required by many states and by all military installations.
Aquatic	
Storm water runoff from the site into adjacent aquatic environments could contain some additional sediment and contaminants because of soil disturbances during site preparation, such as grading. Mitigating measures such as spill response and runoff control should minimize adverse impacts.	Storm water runoff from the site into adjacent aquatic environments could contain some additional sediment and contaminants because of soil disturbances during site preparation, such as grading. Mitigating measures such as spill response and runoff control should minimize adverse impacts.

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Threatened and Endangered Species	
Any possible effects on threatened and endangered species would be a site-specific consideration and would have to be evaluated and analyzed when a specific site is considered as a treatment location. If a site must be used or impacts cannot be avoided, the Army or appropriate DoD authority would work with Federal and/or state authorities to implement appropriate mitigating measures for that particular species and site. Mitigating measures could include habitat protection or improvement at another location or restrictions on operations at the site.	Any possible effects on threatened and endangered species would be a site-specific consideration and would have to be evaluated and analyzed when a specific site is considered as a storage location. Consideration of this issue would be part of the site-selection process. If a site must be used or impacts cannot be avoided, the Army or appropriate DoD authority would work with federal and/or state authorities to implement appropriate mitigating measures for that particular species and site. Mitigating measures could include habitat protection or improvement at another location or restrictions on operations at the site.
Waste Management	
All non-stockpile CWM considered in this environmental impact statement would be managed as a hazardous waste. A transportable treatment system used to treat this CWM would be considered a hazardous waste TSDF and would have to comply with all applicable RCRA requirements. The setup, operation, closure, and demobilization of the transportable treatment systems would generate a variety of wastes at a particular site. Some of the wastes would be RCRA hazardous waste and some would be nonhazardous waste. The wastes generated in the largest quantities would include neutralents; repackaged industrial chemicals; decontaminated metal containers, munition casings, and metal fragments; and spent decontamination solutions and rinse waters. The facilities used to manage these wastes would include permitted, commercial, RCRA hazardous waste TSDFs; permitted solid waste management facilities; wastewater treatment facilities; and recycling facilities, as appropriate to each waste. Neutralents, repackaged industrial chemicals, and any other waste directly associated with chemical agent would be sent to a permitted, commercial, hazardous waste TSDF. The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated. The appropriate DoD authority, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process. The wastes would be managed in accordance with all applicable federal, state, and local laws and regulations.	All non-stockpile CWM considered in this environmental impact statement would be managed as a hazardous waste. A facility used to store this CWM would be considered a hazardous waste TSDF and would have to comply with all applicable RCRA requirements. The setup, operation, and closure of a long-term storage facility would generate a variety of wastes at a particular site. Some of these wastes could be RCRA hazardous waste and some would be nonhazardous waste. The wastes generated during storage could include spill cleanup materials and spent decontamination solutions and rinse waters. Data are not available to estimate the quantity of wastes that could be generated annually. The facilities used to manage these wastes could include permitted, commercial, RCRA hazardous waste TSDFs; permitted solid waste management facilities; wastewater treatment facilities; and recycling facilities, as appropriate to each waste. Any waste directly associated with chemical agent, such as spill cleanup materials, would be sent to a permitted, commercial, hazardous waste TSDF. The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated. The appropriate DoD authority, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process. How wastes would be managed from future treatment of stored CWM cannot be determined at this time since the treatment technologies, methods, or processes are not yet known.

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Waste Management (Concluded)	
In selecting specific, permitted, commercial hazardous waste TSDFs to manage the hazardous waste generated, the Army would consider such factors as the operating and compliance history of the facility and the type of monitoring and pollution control equipment present at the facility. In addition, the Army would perform continuing assessments and audits of all hazardous waste TSDFs selected to ensure that these facilities maintain compliance with all applicable environmental and safety requirements. Under RCRA land disposal restrictions, some of the waste sent to a commercial hazardous waste TSDF, such as neutralents and repackaged industrial chemicals, would require treatment before it could be disposed while some could be disposed of in a hazardous waste landfill without any further treatment. Treatment methods that could be used for various wastes include combustion, wet air oxidation, chemical or electrolytic oxidation, carbon adsorption, and deactivation. The specific treatment method used would be determined on a site-specific and waste-specific basis and would depend on the specific composition of the waste stream being managed. The volume of waste generated annually would depend upon such factors as the number and types of treatment systems deployed and the type and quantity of CWM treated by each deployed system. On a national basis, the quantity of hazardous waste estimated to be generated annually would represent a small to insignificant increase in the quantity of waste managed annually at commercial hazardous waste TSDFs. The quantity of nonhazardous waste estimated to be generated annually would represent an insignificant increase in the quantity of such waste managed annually by nonhazardous waste disposal facilities and recycling facilities. Impacts to local waste management facility capacities would be site-specific and would have to be addressed in the site-specific environmental reviews that would be prepared for each site.	
Utilities	
Water Supply	
Up to 8,000 gals/day of potable water could be needed for a large-scale deployment The impact of the increased water demand on an installations or local water utility would be site-specific and depend on the number of systems deployed and the capacity of the local system. At large military installations and urban sites served by water utilities with excess capacity, the impact would likely be small. At smaller military installations, sites served by water utilities with little or no excess capacity,	Impacts to local or regional utilities would be relatively minor. Relatively small amounts of electrical power would be needed to operate storage facility (igloo or IHF) lighting, monitoring systems, and security systems. Water supply and sanitary waste disposal would be needed in the short term for the personnel needed to prepare the site and storage facilities and in the long term for the few personnel needed to provide security and monitoring at the site.

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Utilities (Concluded)	
Water Supply (Concluded)	
and sites in arid regions the increased demand could cause adverse impacts on the utility and other water supply users including loss of line pressure, increased sediment entrainment due to higher flows, and increased depletion of local water sources.	The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.
Wastewater Disposal	
About 2,500 gal/day of non-hazardous sanitary wastewater could be generated by a large-scale deployment requiring disposal. Additional non-hazardous wastewater could also be generated by rinsing and cleaning activities. Impacts would be site-specific and depend on the number of systems deployed and the capacity of the local system. At large military installations and urban sites served by wastewater treatment facilities with excess capacity, the impact would likely be small. However, local impacts could occur if local sewer lines did not have the capacity to handle the flow. At smaller military installations and sites served by wastewater systems with little or no excess capacity, the increased demand could cause adverse impacts on the utility and other sewer system users.	
Electric Utilities	
Up to 1,880 kW of continuous electrical power could be needed for a large-scale deployment site. Where local power would be used, the impact on the utility and its users would be site-specific and depend on the number of systems deployed and the capacity of the local power system. At large military installations and urban sites served by an electric utility and line infrastructure with sufficient capacity, the impact would likely be small. At sites served by small electric utilities or lower capacity transmission infrastructures, the impacts on the utility and other users could be significant and include line voltage drops, degradation of line power quality, and system failures.	
Traffic and Transportation	
Adverse impacts to transportation resources surrounding locations with non-stockpile CWM are likely to be minor and temporary. Potential impacts to traffic and transportation due to site preparation, setup, normal operations, demobilization, and closure activities could include increases in truck and automobile traffic on public roads and highways near the treatment site, increased congestion, noise, and increased risk of traffic accidents.	Potential traffic and transportation impacts would result primarily from the site preparation and setup activities and from transfer of non-stockpile CWM from the discovery site to the storage site. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Traffic and Transportation (Concluded)	
Traffic disruption could occur if new access roads or modifications to existing roads were necessary to bring in the transportable chemical treatment and support systems or to facilitate movement of non-stockpile CWM from a discovery site to the treatment site. Transporting non-stockpile CWM to a distant treatment location would likely have minor impacts on existing roads and highways. Impacts could include increases in traffic and increased risk of transportation accidents involving releases of CWM. It is not likely that the increase in traffic would cause major changes in local traffic patterns.	
Cultural Resources	
Cultural and historical resources, archeological sites, and Native American lands and religious areas could either be directly or indirectly affected by activities, including ground excavation, noise and vibration, access restrictions, evacuation requirements, visual impairments, air emissions, and accidental releases of CWM. Impacts could include (1) potential disturbance or destruction of cultural, historic, or archeological sites, structures, or resources, (2) potential disruption or destruction of Native American religious areas, sacred sites, rituals, and traditional hunting or fishing grounds, and (3) disturbance of previously unknown Native American gravesites. Prior to undertaking site preparation and setup activities, site-specific consultations, research, and field surveys would be performed to identify whether the siting of any of the systems or support equipment would affect historic or cultural resources. Consultations with appropriate federal agencies and State and Tribal Historic Preservation Offices would be conducted. Additionally, Native American groups and representatives would be contacted to determine potential Native American concerns with the direct use of land and land that could be indirectly impacted by non-stockpile CWM activities. By following the appropriate state, federal, and tribal protocols, disturbance to culturally important, historic, and archeological resources and Native American lands would be avoided or minimized to the greatest extent possible.	At sites where no existing storage facilities are available, site preparation would require trees and vegetation to be cleared in order to establish a clear zone for the deployment of an IHF. The potential for adverse impacts to historic and culturally significant resources and lands of importance to Native Americans could result from (1) long-term conversion of land use, (2) physical disturbance of land, (3) noise generated during site preparation activities, and (4) t he potential for accidental releases of non-stockpile CWM. Prior to undertaking site preparation and setup activities, site-specific consultations, research, and field surveys would be performed to identify whether the siting of any of the systems or support equipment would affect historic or cultural resources. Consultations with appropriate federal agencies and State and Tribal Historic Preservation Offices would be conducted. Additionally, Native American groups and representatives would be contacted to determine potential Native American concerns with the direct use of land and land that could be indirectly impacted by non-stockpile CWM activities. By following the appropriate state, federal, and tribal protocols, disturbance to culturally important, historic, and archeological resources and Native American lands would be avoided or minimized to the greatest extent possible.

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Cultural Resources (Concluded)	
Impacts related to the transport of non-stockpile CWM from the discovery site to a distant treatment location could be caused by noise, vibration, and air emissions from transport trucks and military aircraft moving non-stockpile CWM items to a treatment location. The extent of such impacts would be site-specific and would depend on the proximity of culturally important resources or lands to the transport routes, the sensitivity of the resources to transport-related impacts, and the amount of non-stockpile CWM to be moved.	The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.
Land Use	
The transportable chemical treatment and support systems could require between 1 and 6 acres of land, depending on the number of systems deployed and additional land areas that could be affected if other improvements are required (for example, access road and utilities). Land use impacts could include (1) potential conflicts with existing adjacent land uses, (2) conflicts with sensitive land uses, (3) delays in new uses of underlying or nearby lands, and (4) impacts on private lands. Potential for adverse land use impacts could occur if establishment of controlled areas exceed site or property boundaries and planned evacuations are required. Evacuations would occur during daylight working hours if needed. Transport of non-stockpile CWM to an off-site treatment location could create land use conflicts including use of addition land to construct helicopter land areas, noise from the landing and takeoff of helicopters that would be used in transporting non-stockpile CWM, and impacts to land uses along the transport route.	In most cases, deployment of an IHF or use of existing storage magazines or igloos at large, active military installations would not conflict with existing land uses on the installations. At small military installations, properties not under government control, and, possibly, at inactive military installations, deployment of an IHF and long-term storage of non-stockpile CWM could conflict with existing or surrounding land uses. Storage of non-stockpile CWM would preclude other uses of the land until such time as the CWM items were processed or moved to an off-property treatment location. In addition, depending on the need for and size of controlled areas established as a result of evaluating potential accidents, the potential exists that arrangements would have to be made to use private or non-military property or to restrict uses and activities on adjacent private or non-military property. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.
Socioeconomic Characteristics	
An estimated 18 to 98 non-local workers could be required to setup, operate, and demobilize the transportable chemical treatment and support systems. Potential socioeconomic impacts could result from increased needs placed on existing community infrastructures and services by in-migrating workers (for example, increased need for housing) and increased demands placed on the use of emergency, hospital, and medical facilities and personnel. If adequate housing is not available, the operations contractor would provide temporary housing for on-site personnel.	Potential socioeconomic impacts could result from needs placed on existing community infrastructures and services by in-migrating workers and by disruptions and evacuations that could be caused by non-stockpile CWM handling and storage. The community impacts due to in-migrating personnel would be very small. Local contractors and labor would probably conduct site preparation and building modification or setup. The greatest in-migration of personnel would occur to accomplish the recovery and transfer of non-stockpile CWM from the discovery site to the IHF or

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Socioeconomic Characteristics (Concluded)	
Establishment of controlled areas could require temporary evacuations of populations if controlled areas exceed site or property boundaries. Evacuations could cause significant direct and indirect socioeconomic impacts depending on the areas affected and the length of time of any required evacuations. The types and levels of socioeconomic impacts that could be caused by non-stockpile CWM activities would be site-specific and would vary based on (1) the local demographic and geographic setting of the sites where activities would occur; (2) the number of systems deployed to a site, and (3) the duration of activities.	existing storage facilities. These personnel would come without families and if housing were not available, the contractor would provide temporary mobile living quarters. The number would probably be less than 20. Because the recovery and transfer operations would be of limited duration, it is likely that the presence of these personnel would have a small and short-lived impact on the surrounding community. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.
Public Health and Safety	
Under normal operations, the setup, operation, closure, and demobilization of the transportable treatment systems would not be expected to pose any significant threat to public health and safety. However, truck and automobile traffic would temporarily increase on roads in the vicinity of the treatment site and could possibly result in the possibility of a small increase in the number of traffic accidents on such roads. Activities that disturb the ground surface would generate fugitive dust emissions that could drift offsite. Appropriate dust suppression measures would be carried out to minimize or eliminate the potential public health consequences from the release of fugitive dust. Site-specific impacts and the need for any site-specific mitigating measures would have to be evaluated and analyzed when a specific site is considered as a treatment location. Emergency response plans, including a site emergency response plan and a transportation emergency response plan, would be prepared and implemented before any items containing chemical agent or industrial chemicals were handled, treated, or processed at a specific site. Children would be unlikely to be exposed to disproportionate health or safety risks from treatment system. This would need to be verified in the site-specific environmental reviews that would be prepared for each site.	Under normal operations, the setup, operation, closure, and demobilization of the storage facility would not be expected to pose any significant threat to public health and safety. However, truck and automobile traffic could increase on roads in the vicinity of the storage site and could possibly result in the possibility of a small increase in the number of traffic accidents on such roads. Activities that disturb the ground surface would generate fugitive dust emissions that could drift offsite. Appropriate dust suppression measures would be carried out to minimize the potential public health consequences from the release of fugitive dust. Site-specific impacts and the need for any site-specific mitigating measures would have to be evaluated and analyzed when a specific site is considered as a storage location. Emergency response plans, including a site emergency response plan and a transportation emergency response plan, would be prepared and implemented before any items containing chemical agent or industrial chemicals were transported to the storage facility or stored in the facility. Children would be unlikely to be exposed to disproportionate health or safety risks from storage activities. This would have to be evaluated and analyzed when a specific site is considered as a storage location. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known.

Table ES-6. (Continued)

Preferred Alternative	No Action Alternative
Environmental Justice	
A potential for disproportionate impacts to minority and low-income populations could occur in site selection and in choices made related to the conduct of treatment operations themselves. Potential impacts could include (1) lost economic opportunity, as new developments choose not to locate in areas in which non-stockpile CWM treatment and processing operations occur; (2) lower property values; (3) potential evacuation impacts; and (4) an increase in the potential for human health and safety impacts. In addition, recovery, storage, or treatment activities would preclude other uses of the land for the duration of the site preparation, treatment operations, and site closure. This could prevent beneficial redevelopment of the treatment site location, especially at closed military bases and other properties. The potential for disproportionate environmental impacts to minority or low-income communities would depend on the location of the treatment sites and the presence and proximity of minority or low-income communities to these sites.	A potential for disproportionate impacts to minority and low-income populations could occur in site selection for temporary storage facilities. Potential impacts could include (1) lost economic opportunity, as new developments choose not to locate in areas in which non-stockpile CWM is stored; (2) lower property values; (3) potential evacuation impacts; and (4) an increase in the potential for human health and safety impacts. In addition, recovery and storage activities would preclude other uses of the land until the CWM items were processed or moved to an off-site treatment location. This could prevent beneficial redevelopment of the treatment site location, especially at closed military bases and other properties. The impacts at future treatment sites cannot be determined at this time because the technologies, processes, or methods are not yet known. The potential for disproportionate environmental impacts to minority or low-income communities would depend on the location of the storage sites and the presence and proximity of minority or low-income communities to these sites.
Cumulative Impacts	
Various other ongoing or future planned actions could occur in the vicinity of any site used to treat CWM in a transportable treatment system and/or any site used to manage wastes generated from the transportable treatment system. The cumulative impacts at any site from the transportable treatment systems and these other actions would be very site-specific and would depend on the nature, location, and number of such other actions. These cumulative impacts would have to be evaluated and analyzed when a specific site is considered as a treatment location. The only cumulative impact that can be quantified on a national basis relates to the volume of waste generated from the transportable treatment systems. This impact is discussed above under waste management.	The cumulative impacts from the long-term storage of non-stockpile CWM would include the impacts from the storage itself, plus the impacts from the ultimate treatment of the CWM being stored, plus the impacts from various other ongoing or future planned actions that could occur in the vicinity of any site used for long-term storage of CWM, any site used in ultimately treating the stored CWM, and/or any site used to manage wastes generated from the storage and ultimate treatment of the CWM. These impacts would all be very site specific. Furthermore, the treatment technologies, processes, or methods that would ultimately be used are not known at this time, and consequently their impacts cannot be analyzed at this time. As a result, the cumulative impacts of long-term storage of the CWM cannot be meaningfully analyzed at this time.

[a]Normal operation means that all activities and operations take place as designed , as planned, and within regulatory limits.

CWM – Chemical warfare materiel
IHF – Interim holding facility
HAP – Hazardous air pollutant
MMD-2 – Munitions Management Device–Version Two
RCRA – Resource Conservation and Recovery Act
TSDF – Treatment, storage, and disposal facility

Table ES-7 Comparison of Alternatives if Hazardous Substances are Accidentally Released

Preferred Alternative	No Action Alternative
Risk Associated with Accidental Release	
In general, the accidental release of chemical agent and industrial chemicals contained in CWM items during handling, transport, or treatment could cause adverse health impacts, including injury and death, mainly within the controlled areas where no members of the general public would be expected to be present. Therefore, risks for such operations, in particular for CWM items without explosive components, fall in the lower to intermediate risk group categories. However, the treatment of CWM items with explosive components, as well as the transport of CWM items by aircraft poses greater risk. Accidental release of industrial chemicals and treatment wastes during transport to a commercial treatment facility could lead to adverse health impacts as a result of exposure to volatile chemical compounds. However, the severity of such release is much less than that associated with chemical agent release from accidents during handling, transport, and treatment of CWM items.	Risks associated with continued storage of recovered CWM items fall in the lower to intermediate risk group categories. However, because the CWM items would eventually be treated and destroyed at some time in the future, risk from continued and prolonged storage is an additional risk not present in the preferred alternative. As CWM items deteriorate with age, there is also a potential for an increase in the frequency of accidental explosive detonations during handling, transport, and treatment of CWM items with explosive components. Risks associated with transporting CWM to and from a storage location would be the same as the preferred alternative. Risks associated with future treatment of stored items cannot be determined because the treatment technologies, processes, and methods are not yet known.
Ecological Environment	
Accidental releases of agents or industrial chemicals through spills or explosive releases could lead to adverse immediate and acute impacts, including injury and death, in the immediate area of the release. Except for highly volatile agents or explosive releases, most spills of agents, reagents, and treatment wastes would have little impact beyond the immediate area of a spill, unless sufficient concentrations are transported downwind through dispersion of aerosols or gases. Long-term impacts are unlikely because releases of most agents or wastes would be contained onsite, the agents are relatively non-persistent, and cleanup plans would be enacted to further reduce the threat. Explosive or volatile releases would also not create a long-term threat because of the rate of degradation of agents and wastes and because of the cleanup that would be undertaken upon release. Arsenic would be long-lived in the environment unless cleaned up. Regardless of the location or type of accidental release, contingency plans would be implemented to clean up any resulting contamination.	Accidental releases of agents or industrial chemicals through spills or explosive releases could lead to adverse immediate and acute impacts, including injury and death, in the immediate area of the release. Except for highly volatile agents or explosive releases, most spills of agents would have little impact beyond the immediate area of a spill, unless sufficient concentrations are transported downwind through dispersion of aerosols or gases. Long-term impacts are unlikely, as releases of most agents would either be contained on-site until cleanup, or would be constrained by the containment afforded by the storage facility. Explosive or volatile releases that penetrate the storage facility would have impacts similar to those described for the proposed action and would be unlikely to create any long-term impacts. Arsenic would be long-lived in the environment unless cleaned up. Regardless of the location or type of accidental release, contingency plans would be implemented to clean up any resulting contamination.

Table ES-7. (Concluded)

Preferred Alternative	No Action Alternative
Ecological Environment (Concluded)	
Spills of petroleum products would be unlikely to have an impact because the volume that could be spilled would be small and standing operating procedures would be in place to contain any spill and remove contaminated soils from the site before groundwater or surface waters could be affected.	Spills of petroleum products would be unlikely to have an impact because the volume that could be spilled would be small and standing operating procedures would be in place to contain any spill and remove contaminated soils from the site before groundwater or surface water could be affected. The impacts of accidents at future treatment sites cannot be determined because the treatment and processing methods are not yet known.
Human Health Effects	
Accidental releases of chemical warfare agents have the potential to cause injury and death if the release results in exposure. Airborne chemical warfare agent s and the agent breakdown products EA 2192, 2-chlorovinyl arsenous acid, and inorganic arsenic represent the principal acute threats from accidental release. Chemical warfare agents are short-lived substances that are unlikely to represent chronic threats. However, the breakdown products inorganic arsenic, 2-chlorovinyl arsenous acid, and EA 2192 have the potential to present chronic threats. Accidental releases of industrial chemicals, treatment chemicals, and neutralent waste chemicals have the potential to cause injury primarily through their irritant and/or incapacitating properties, although some can be lethal at high concentrations. The likelihood of exposure to the volatile chemicals—such as phosgene, chloroform, and t-butyl alcohol—would be higher than for the other chemicals. However, these chemicals are generally not persistent in air, and any exposure that might occur would be limited by their rapid dissipation and environmental degradation to form relatively innocuous breakdown products at most sites. Generally, the probability of accidental release would be small, and the probability of exposure would therefore also be small. In the event of an accidental release, the probability of exposure would still be small because of the planning and review involved in siting of the mobile treatment facility, contingency plans developed by the Army, and other site-specific factors.	Accidental releases of chemical warfare agents have the potential to cause injury and death if the release results in exposure. The substances identified as presenting the principal acute and chronic threats under the proposed action would also present the principal threats under the no-action alternative. In the event of an accidental release, the probability of exposure would still generally be small because of the planning and review involved in siting of the storage facility, contingency plans developed by the Army, and other site-specific factors. The impacts of accidents at future treatment sites cannot be determined because the treatment and processing methods are not yet known.

CWM – Chemical warfare materiel

Section 1

Purpose of and Need for the Action

The Army must destroy various types of chemical warfare materiel (CWM) that are currently stored at military installations or that will be recovered in the future from burial sites or test and firing ranges throughout the United States and its territories. This CWM is called non-stockpile CWM. Non-stockpile CWM comprises those CWM items that are not part of the current U.S. stockpile of chemical munitions (referred to as stockpile CWM) stored at eight locations in the United States and on Johnston Island in the Pacific Ocean (Section 1.5). The Army must destroy both the non-stockpile and stockpile CWM (1) to ensure protection of public health and safety and the environment from the hazardous materials contained in the CWM, (2) to comply with an international treaty that requires its destruction, and (3) to comply with federal legislation (Section 1.1).

Non-stockpile CWM comprises a wide variety of munitions, containers, equipment, and facilities. However, this programmatic environmental impact statement is concerned with only a portion of this materiel. These are non-stockpile chemical munitions, containers of chemicals that are not munitions, and chemical agent identification sets (CAIS). These items are currently buried at a number of locations in the United States and its territories or are in storage at military installations (Section 1.5).

The U.S. Army is the designated Department of Defense (DoD) Executive Agent for destroying CWM. The Army has implemented the Non-Stockpile Chemical Materiel Project (NSCMP) to develop safe methods and systems to destroy non-stockpile CWM (Section 1.4). The NSCMP is responsible for processing and treating non-stockpile CWM. The military installation or the U.S. Army Corps of Engineers is responsible for managing and remediating CWM burial sites and stored CWM (Section 1.8).

An important activity of the NSCMP is to develop transportable systems that can be moved from one location to another to treat non-stockpile chemical munitions, containers of chemical agents other than munitions, and CAIS (Section 1.2). A number of treatment technologies and methods are under study by the Army. Research and development on four such treatment systems has reached the point of maturity that compels the Army to decide whether it wants to complete development and make the systems available for deployment in the field.

The action proposed by the Army, and analyzed in this environmental impact statement, is to complete the development and testing of all four transportable treatment systems so that they would be available to be used in the future where needed and appropriate to treat and process stored non-stockpile CWM and non-stockpile CWM recovered from burial sites and test and firing ranges. Section 2.0 and Appendix C describe the four systems. The Army

would also continue to assess and evaluate the treatment potential of other technologies, methods, and processes, such as those being considered in the Assembled Chemical Weapons Assessment Program and the Alternative Technologies and Approaches Program. Some of these technologies, methods, and processes are described in Appendix G.

This environmental impact statement has been prepared under the requirements of the National Environmental Policy Act; the Code of Federal Regulations (CFR), Title 40, Parts 1500-1508; Army Regulation 200-2; and Executive Orders. The purpose of t he document is to provide Army decision-makers with information on the possible environmental consequences of the proposed Army action and alternatives to it. Section 1.11 describes Army activities to date to obtain public input to this environmental impact statement.

This environmental impact statement is programmatic in nature because the Army is only deciding at this time whether to complete development of the four transportable treatment systems so that they would be available in the future for deployment in the field. The Army is not deciding how and where these systems would be deployed to treat and process items at specific CWM burial or storage sites. These would be site-specific decisions that would be made separately in the future for each location only after additional environmental review, public involvement, and consultation with the appropriate federal, tribal, state, and local authorities.

1.1 Need for the Action

There are several reasons why the Army must destroy non-stockpile CWM, including the types of CWM considered in this environmental impact statement. These reasons are to protect human health and safety and the environment, to comply with an international treaty known as the Chemical Weapons Convention that requires such destruction, and to execute the requirements of the U.S. Congress.

1.1.1 Protect Public Health and Safety and the Environment

Non-stockpile CWM is currently buried in the ground at a number of sites in the United States (see Section 1.5.3) and is stored in buildings at military installations. CWM poses a potential threat to human health and safety and to the environment because of the hazardous nature of its chemical contents. These materials in buried CWM could leak into the environment or be accidentally released during ground-disturbing activities. Material could also be released accidentally from stored CWM if an external event occurs at a storage location, such as an earthquake, tornado, or an airplane crash into a storage structure. Military installations and the U.S. Army Corps of Engineers are responsible for managing CWM burial and storage sites to protect public health and safety (Section 1.8). The NSCMP is not responsible for determining whether burial sites or test ranges that may contain non-stockpile CWM should be remediated. However, the NSCMP is responsible for destroying

non-stockpile CWM once it has been presented to the NSCMP for processing and treatment after being removed from storage or recovered from a burial site or test range.

1.1.2 Comply with the Chemical Weapons Convention

The Army must destroy non-stockpile CWM to comply with the *Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction.* This convention is an international treaty commonly referred to as the Chemical Weapons Convention or CWC. The treaty was signed by the United States on 13 January 1993 and ratified by the U.S. Congress on 25 April 1997. The convention is an international arms control agreement designed to destroy all chemical weapons and chemical weapon production facilities that meet the criteria set forth in the treaty, eliminate the threat of chemical warfare, and enhance global stability. The Chemical Weapons Convention is described in Appendix H.

The Convention specifies the time period for destroying chemical warfare materiel. Non-stockpile CWM items in storage at the time of treaty ratification must be destroyed within two, five, or ten years of the ratification date, depending on the type of chemical weapons or on the type of chemical with which an item is filled. CWM recovered from the ground or from test and firing ranges after ratification of the treaty must be declared under the Convention and destroyed as soon as possible. Parties to the Convention can apply for extensions of the destruction deadlines.

Non-stockpile CWM buried before 1 January 1977 is excluded from the treaty requirements as long as it remains buried. This materiel does not have to be declared under the treaty or destroyed as long as it remains buried. However, this CWM may have to be dug up and removed from burial sites for various reasons. A common reason is that a determination has been made that the buried items pose a threat to human health and safety or to the environment if they remain in the ground. If the item can be safely handled and is removed from the ground, the recovered CWM must be identified, declared under the Chemicals Weapon Convention, inspected, and destroyed in accordance with the requirements of the Convention.

1.1.3 Comply with the Requirements of the U.S. Congress

The *National Defense Authorization Act of 1993* (Public Law 102-484) required the Army to submit a report to Congress setting forth the Army's plan for destroying non-stockpile CWM after U.S. ratification of the Chemical Weapons Convention. Congress instructed the Army to (1) identify the locations, types, and quantities of non-stockpile CWM, (2) discuss destruction options, and (3) estimate the cost and schedule for its destruction. The Army has prepared a draft report entitled *Survey and Analysis Report* (Department of the Army, 1996a) describing the known and likely locations and the quantity

of non-stockpile CWM. The Army has also published an *Implementation Plan* (Department of the Army, 1995) that describes how the Army intends to carry out the NSCMP.

1.2 Purpose of the Action

The purpose of the proposed Army action (preferred alternative) is to make available safe and cost-effective transportable treatment capability that can be used to treat or repackage chemicals in non-stockpile CWM items so that the resulting waste products can be handled within the existing commercial hazardous waste treatment and disposal system in the United States. The Army needs transportable CWM treatment systems because of the large number of burial and storage sites and because many of these sites have only a small number of CWM items.

There are currently 168 sites at which non-stockpile CWM is believed to be buried, suspected to be buried, or currently stored (Department of the Army, 1996a). Most of these sites are known to have or are suspected of having only a small number of items. Because of this, the Army has determined that it is not feasible to design and construct fixed processing and treatment facilities at all of these locations. Therefore, the Army must develop transportable systems that can be moved to a number of locations.

To accomplish the mission, the NSCMP must be able to process and treat a wide variety of types of non-stockpile CWM items (see Section 1.5 and Appendix B). The Army has designed four types of transportable treatment systems in order to handle the various types of items in the safest and most cost-effective manner.

1.3 Scope of Environmental Review

The Army is carrying out the required environmental review for processing and treating non-stockpile CWM in two steps. The first step is the programmatic review documented in this environmental impact statement, which will be used as input to the programmatic decision about whether to complete development of the four transportable treatment systems and make them available for deployment. The Army is not making any decisions as part of this first step of environmental review about deploying any of these systems to specific burial or storage sites or to any other specific location. If the preferred alternative is selected, the second step of environmental review would take place in the future when a decision is to be made about deploying a system or systems at a specific location. Public comment and input are elements of both steps.

This Army approach to environmental review is referred to as tiering, which is allowed and encouraged under the regulations of the U.S. Council on Environmental Quality (40 CFR 1502.20). The results of the first step (tier) of environmental analysis would be incorporated as appropriate in the second, site-specific step (tier) of environmental review.

1.3.1 Scope of Programmatic Environmental Impact Statement

This environmental impact statement is programmatic in nature to provide environmental information for the programmatic Army decision about whether to complete development of four specific treatment systems described in Section 2 and Appendix C and make them available for deployment. The scope of the environmental review required for the proposed action is programmatic because the decision is only whether the Army should complete development of the four transportable treatment systems, not whether to deploy the completed systems to specific sites. Future site-specific decisions about deployment require additional site-specific analyses that have not been carried out as part of this programmatic environmental review.

1.3.2 Alternatives Considered for Analysis

The Army has considered a number of ways that non-stockpile CWM could be processed and treated to meet the NSCMP mission requirements and comply with the Chemical Weapons Convention. These are described in Table 1-1. The preferred alternative and the no-action alternative are analyzed in detail in this environmental impact statement. The Army has determined that the other alternatives would not meet the NSCMP mission requirements or could not be feasibly implemented at this time. Therefore, these alternatives, which involve using the transportable treatment systems with conditions or using technologies or facilities other than the transportable treatment systems, are not analyzed in this environmental impact statement. The reasons why these alternatives are not considered further are discussed in Section 3.3.

1.3.3 Future Environmental Analyses

Should the Army decide after considering public comments on this environmental impact statement to implement the preferred alternative, decisions would then be made in the future about using one or more treatment systems to process and treat CWM stored or recovered from burial sites at specific locations. As part of the second step (tier) of the environmental review process, the appropriate DoD authority would conduct appropriate additional site-specific environmental analyses in the future when a decision is to be made about how to deploy transportable treatment systems at a specific site. The appropriate DoD authority would also conduct required local public involvement activities and consult with federal and state agencies and Native Americans with regulatory responsibilities or interests in specific deployment sites.

Site-specific analyses could be conducted under several statutes or regulations. These include the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA); the *Resource Conservation and Recovery Act of 1976* (RCRA); other similar federal and state statutes; the National Environmental Policy Act; 40 CFR 1500-1508; Army regulations; and Executive Orders. The process would include public comment and input.

Table 1-1. Alternatives Considered for Analysis

Use Transportable Treatment Systems (Preferred Alternative)[a]	
Use transportable treatment systems	Complete development and testing of all four transportable treatment systems described in Section 2 and Appendix C and make them available to be used where needed and appropriate to treat and process non-stockpile CWM. Continue to assess and evaluate the treatment potential of other technologies, methods, and processes.
Use the Transportable Treatment Systems with Conditions[b]	
Store neutralent and other wastes that require thermal treatment	Store neutralent and other wastes from the transportable treatment systems that require combustion as the final treatment method to meet the RCRA land disposal restrictions. Treat these wastes in the future when some method other than combustion is available that meets the RCRA land disposal restrictions.
Restrict the Operating Location of the Treatment Systems	Decide programmatically to restrict deployment of the transportable treatment systems only to locations on the military installation or other property where the CWM items are stored or are being recovered from burial sites or test and firing ranges.
Use Technologies or Facilities Other than the Transportable Treatment Systems[b]	
Use stockpile disposal facilities	Use facilities to be used or proposed for use to destroy the national stockpile of chemical weapons.
Use other treatment methods	Use some other treatment technology, method, or process than those used in the preferred alternative.
Use commercial treatment facilities	Send non-stockpile CWM to commercial facilities with permits to handle, treat, and dispose of hazardous materials.
Build fixed facilities at storage, burial, and recovery sites	Design and construct fixed treatment and processing facilities at locations where non-stockpile CWM is stored, buried, or recovered.
No-Action Alternative[a]	
Take no action at this time, and develop and deploy some other treatment system in the future	Suspend or discontinue developing the transportable treatment systems of the preferred alternative. Continue research and development on other treatment technologies, methods, and processes. When a suitable treatment technology method or process is developed into a transportable or other suitable system, make the system available for deployment after appropriate environmental, safety, and other reviews.

[a]Analyzed in detail in this environmental impact statement.
[b]Not considered further in this environmental impact statement.

CWM – Chemical warfare materiel
RCRA – Resource Conservation and Recovery Act

Overall responsibility for determining if transportable chemical treatment systems would be deployed at a specific site would rest with the appropriate military installation or the U.S. Army Corps of Engineers in conjunction with the appropriate federal, tribal, state, and local regulatory authorities, as described in Section 1.8. Before using these systems at a site, the appropriate DoD authority would obtain either a permit under RCRA or approval under CERCLA (as described in Section 1.7).

1.4 Non-Stockpile Chemical Warfare Materiel Program

The NSCMP provides centralized management and direction for the safe destruction of all non-stockpile CWM in the United States in accordance with all applicable federal, tribal, state, and local laws and regulations. The NSCMP is the DoD coordinator for all matters related to the destruction of non-stockpile CWM. The mission of the NSCMP is as follows:

- Develop, field, and support the necessary capabilities and systems to characterize, contain, transfer, store, treat, and dispose of non-stockpile CWM.
- Develop, field, and support the necessary capabilities for a non-stockpile CWM emergency response operation.
- Support the provisions of ratified international treaties for non-stockpile CWM.

To fulfill its mission to treat and dispose of non-stockpile CWM, the NSCMP must research, develop, test, and evaluate integrated methods that can (1) assess the contents of recovered non-stockpile CWM items, (2) gain access to the chemicals contained in non-stockpile CWM items, and (3) treat non-stockpile CWM in a manner that ensures the protection of human health and safety and the environment. The NSCMP must also coordinate with several DoD services and site authorities that are responsible for remediating CWM burial sites or the cleanup of former test ranges that may contain non-stockpile CWM (see Section 1.8).

Military installations or the U.S. Army Corps of Engineers are responsible for determining whether burial sites or test ranges that may contain non-stockpile CWM should be remediated. However, the NSCMP is responsible for destroying non-stockpile CWM once it has been recovered from a burial site or test range and presented to the NSCMP for processing and treatment.

The Army is the Defense Executive Agent for the destruction of all DoD CWM. The responsible Army official is the Program Manager for Chemical Demilitarization. The Product Manager for Non-Stockpile Chemical Materiel, who runs the NSCMP, reports to the Program Manager (Figure 1-1). More information about the NSCMP is provided on the Internet at http://www-pmcd.apgea.army.mil.

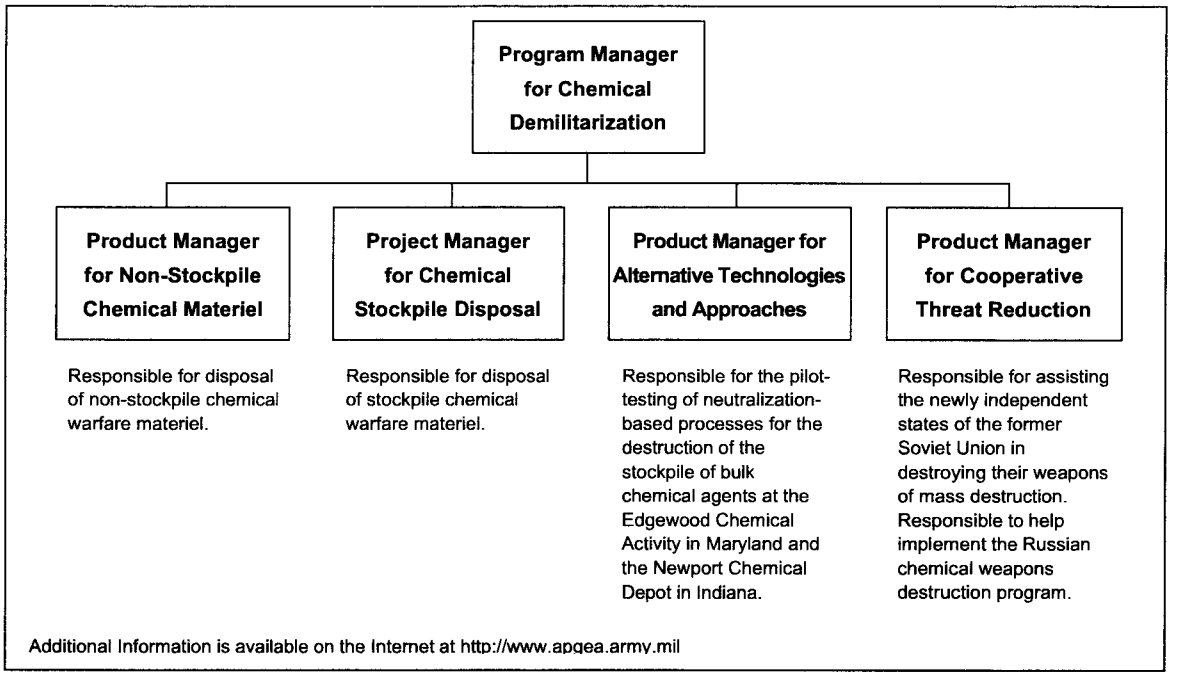


Figure 1-1. Structure of the Army Chemical Demilitarization Program

1.5 Non-Stockpile Chemical Warfare Materiel Considered in this Programmatic Environmental Impact Statement

The United States has two categories of CWM. These are *stockpile CWM* and *non-stockpile CWM*.

Stockpile CWM consists primarily of the former arsenal of unitary chemical weapons and chemical warfare agents stockpiled at eight Army installations in the continental United States and on Johnston Island in the Pacific Ocean. Until recently, this CWM was the active weapons and stored chemical warfare agents that could be used by the military services in time of war. These weapons and materiel are no longer in the active-use weapons arsenal and are being destroyed under the provisions of the Chemical Weapons Convention by the U.S. Army Chemical Stockpile Disposal Program.

Non-stockpile CWM is all other U.S. CWM that is not a part of the U.S. stockpile. Non-stockpile CWM consists of a variety of munitions, containers, equipment, and facilities. There are five categories of non-stockpile CWM:

- **Buried chemical warfare materiel.** CWM deliberately buried as a method of disposal and unexploded CWM on firing and test ranges.

- **Recovered chemical warfare materiel.** CWM recovered from burial sites or firing and test ranges and placed in storage.
- **Miscellaneous chemical warfare materiel.** Unfilled munitions, support equipment, and devices designed for use directly with chemical weapons and program. Includes complete munitions rounds without chemical fill; munitions filled with simulant chemical or inert substances; dummy munitions; empty rocket warheads and motors; projectile cases; other metal and plastic parts components; research and development compounds; chemical samples; and ton containers.
- **Binary chemical weapons.** Former U.S. arsenal of binary chemical weapons and chemicals developed to replace the U.S. arsenal of unitary CWM.
- **Former production facilities.** Facilities used to produce chemical warfare agents.

The categories of buried, recovered, and miscellaneous CWM are the only types of non-stockpile CWM considered in the analysis in this environmental impact statement (Section 1.4) since these are the types of CWM that would be treated by the transportable treatment systems. These types of non-stockpile CWM are currently buried in the ground at a number of locations or are in storage at military installations pending the availability of a system for its treatment and disposal. These CWM consist of the following types of items:

- Chemical munitions
- Containers of chemicals that are not munitions
- Chemical agent identification sets

The Army has other programs and projects under way to determine how to destroy the other types of non-stockpile CWM not considered in this environmental impact statement. The relationship of these programs and projects to the proposed action analyzed in this environmental impact statement is discussed below in Section 1.10.

The three types of non-stockpile CWM considered in this environmental impact statement, characteristics of the chemicals likely to occur in this CWM, and the status of this CWM are described below. More detailed descriptions of the CWM types are provided in Appendix B.

1.5.1 Types of Chemical Warfare Materiel

Transportable treatment systems are being designed to treat chemical munitions (with and without explosive components), chemical containers, and CAIS. Each type of CWM is described below and described in greater detail in Appendix B.

1.5.1.1 Chemical Munitions

Chemical munitions were designed to disperse chemical warfare agents or industrial chemicals onto an enemy target in the form of a liquid aerosol, an unburned residue, or a gas.

Most munitions had an explosive charge for dispersing the chemicals. Some munitions used other methods of dispersal.

Munitions are categorized by the method of their delivery to a target. These categories are shown in Table 1-2. Projectiles, mortar shells, bombs, rockets, missiles, placed munitions, bomblets, and submunitions generally used explosives to disperse the fill material. Spray tanks generally used the force of the air moving past the aircraft or vehicle to force the chemical fill out of the tank. Figures 1-2 through 1-8 shows illustrations of various types of chemical munitions.

1.5.1.2 Containers of Chemicals That Are Not Munitions

Several different types of containers have been used to store or transport chemical agent. These include glass ampoules and bottles, drums, and containers of various sizes up to a one-ton container meeting U.S. Department of Transportation (USDOT) specifications for shipping hazardous materials (Figure 1-9).

1.5.1.3 Chemical Agent Identification Sets

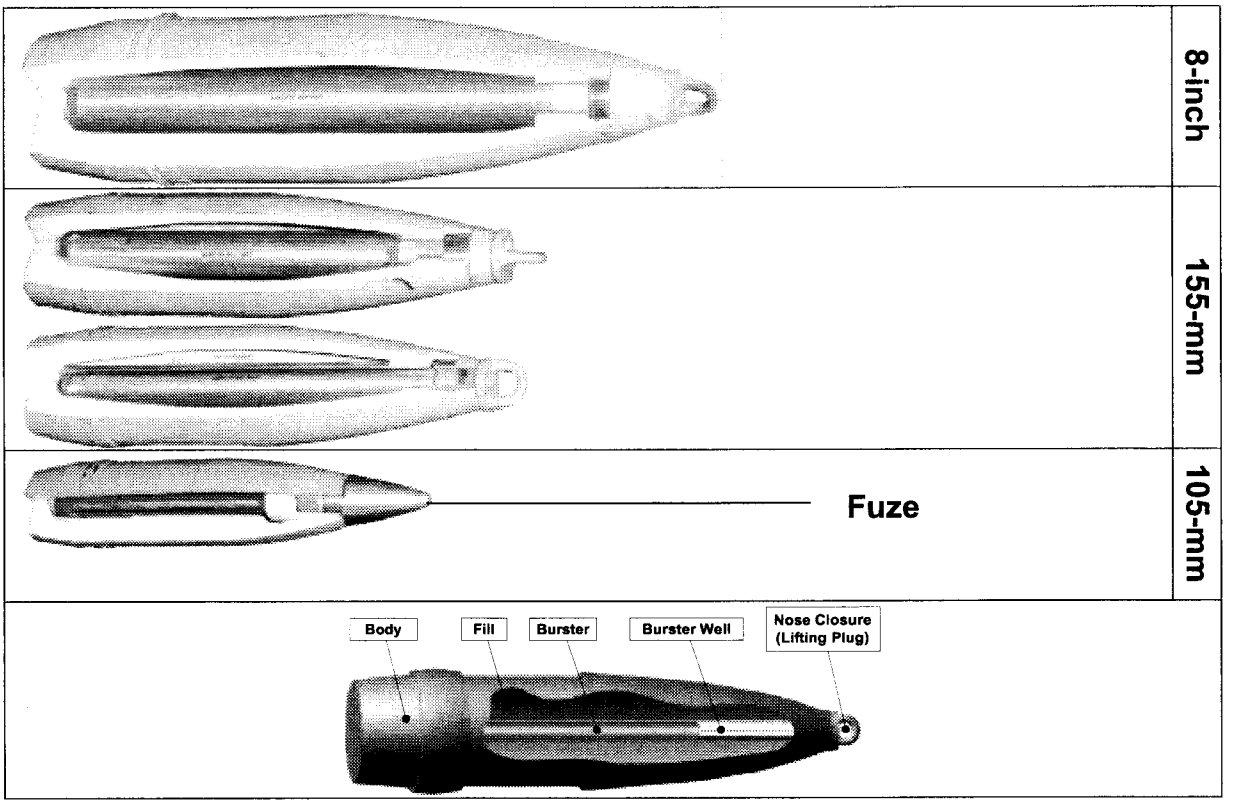
CAIS were used by the military to train soldiers to identify chemical agents in the field. Three major types of CAIS were produced and used during the period 1928 through 1969 and were widely distributed to military organizations. Figure 1-10 shows some examples of CAIS sets.

One major variety of CAIS was an instructional "sniff set" that contained agent-impregnated charcoal. This set was used indoors to teach military personnel how to recognize the odors of chemical agents. The set contained only small amounts of chemical agent.

A second major variety of CAIS, designed for use outdoors, consisted of chemical agent (pure or in solution) in sealed Pyrex® ampoules. The gas tubes would be shattered using a detonator, creating a chemical agent cloud. Soldiers would then try to identify the agent based on its odor and other characteristics. These tubes typically contained more agent than the instructional "sniff sets."

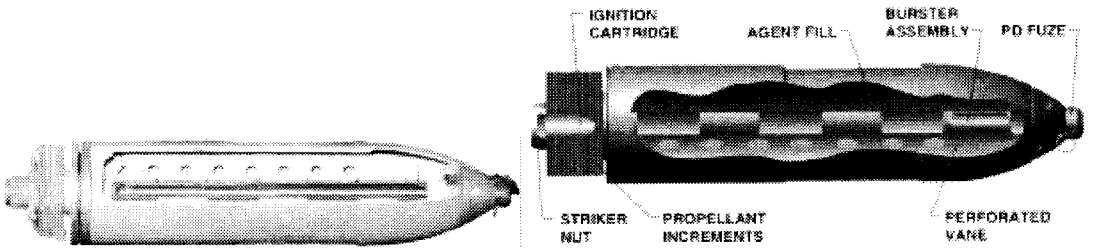
Table 1-2. Types of Non-Stockpile Chemical Munitions

Type	Method of Delivery
Projectiles or mortar shells	Fired from artillery, tanks, or mortar tubes
Bombs	Dropped from aircraft
Rockets or missiles	Fired from launchers on the ground, on ships, or suspended from aircraft
Placed munitions	Put in location by hand (for example, a land mine)
Submunitions or bomblets	Carried inside other types of munitions (for example, a cluster bomb)
Spray tanks	Suspended from aircraft or placed on vehicles



Note: Not to Scale.

Figure 1-2. Typical Chemical Artillery Shells



Note: Propulsion charge (propellant increments and ignition cartridge) on aft end not normally present.

Figure 1-3. Typical Chemical Mortar Shell
(4.2-inch M2/M2A1 for Rifled Bore Mortar Shown)

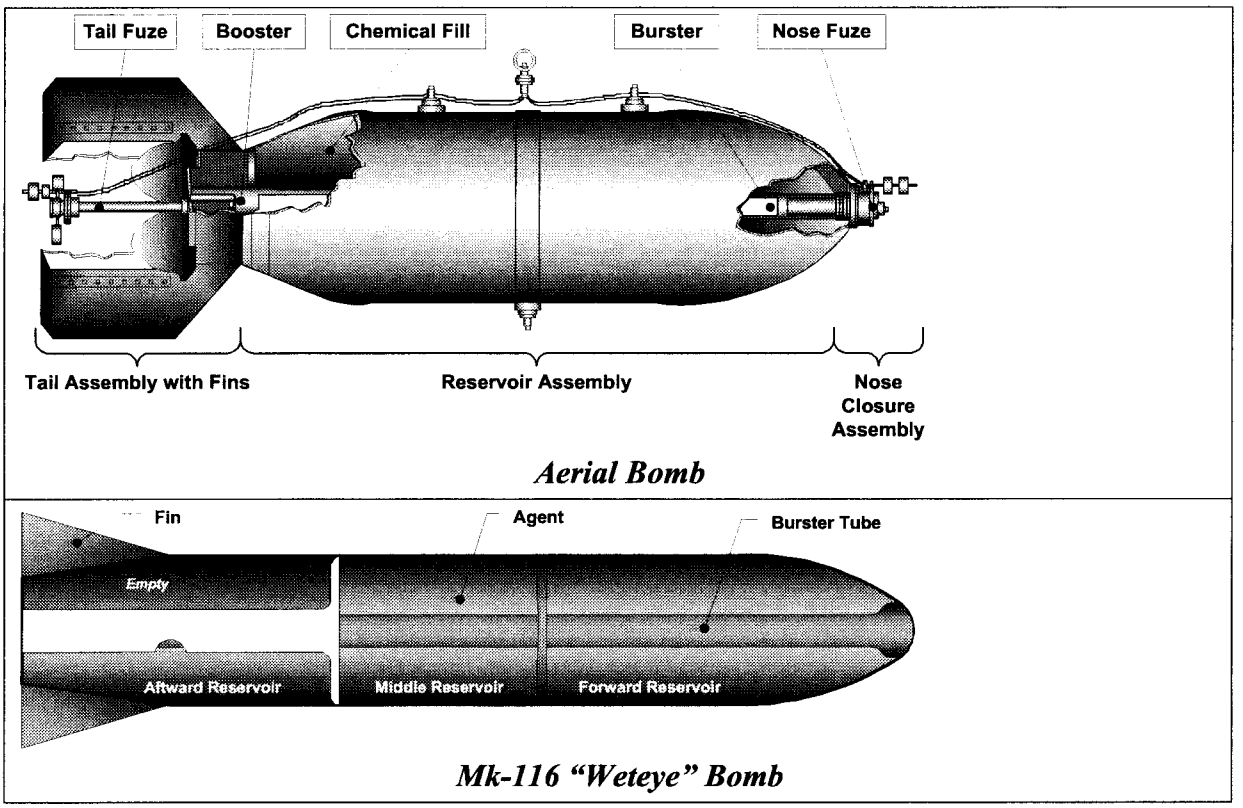


Figure 1-4. Aerial Bombs

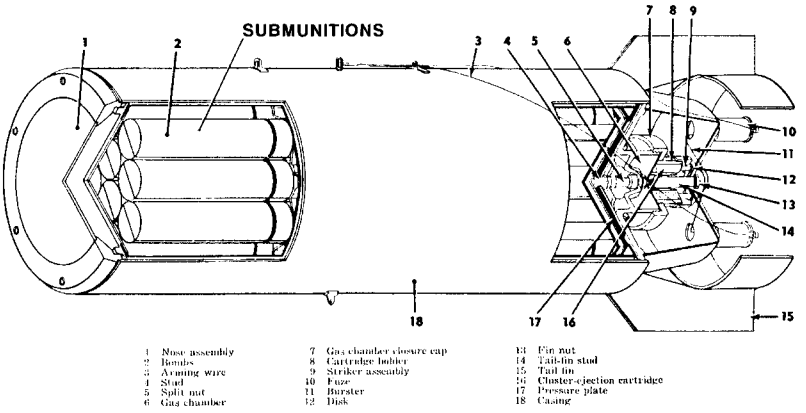


Figure 1-5. Aerial Bomb with Submunitions

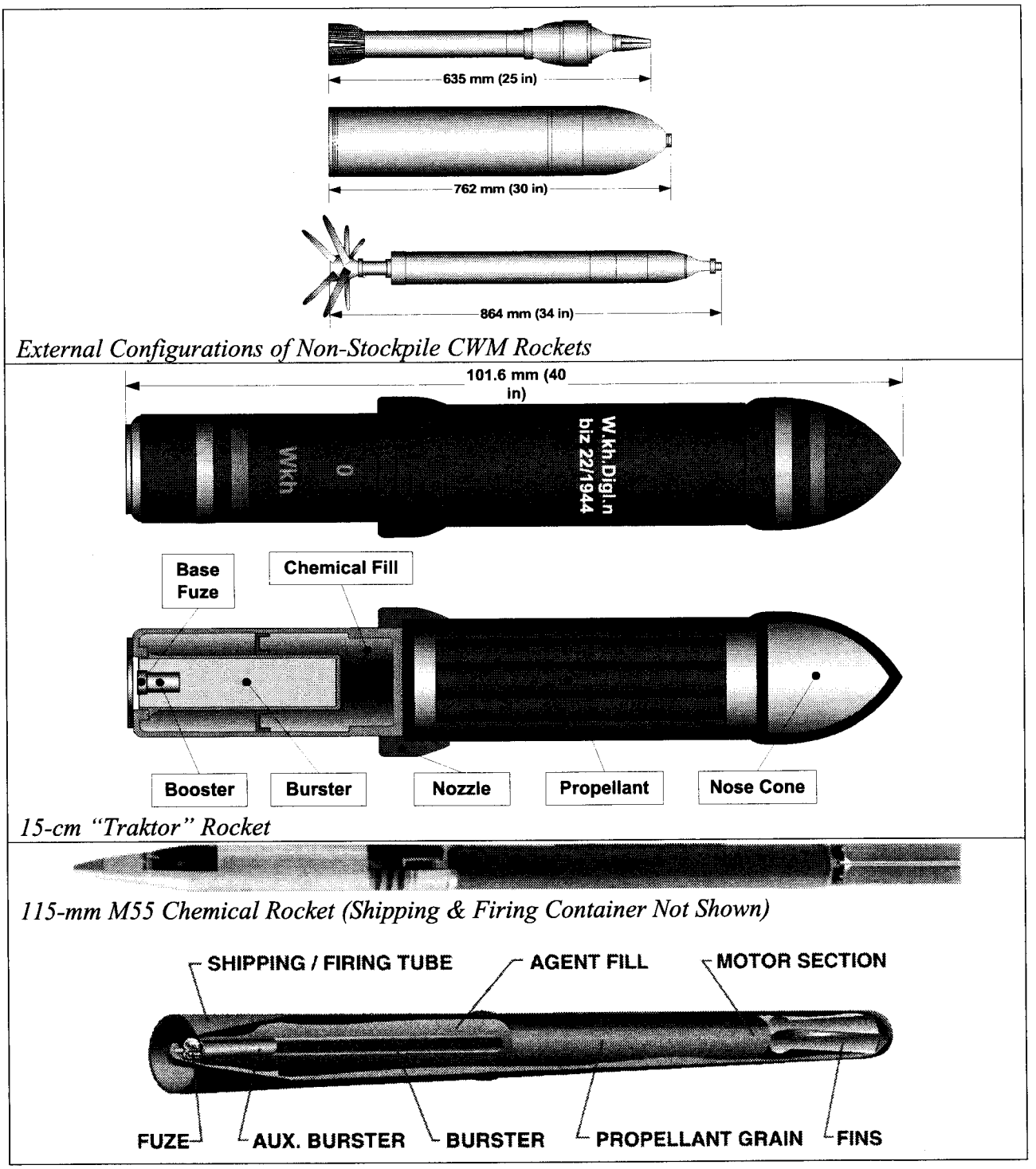


Figure 1-6. Typical Chemical Rockets

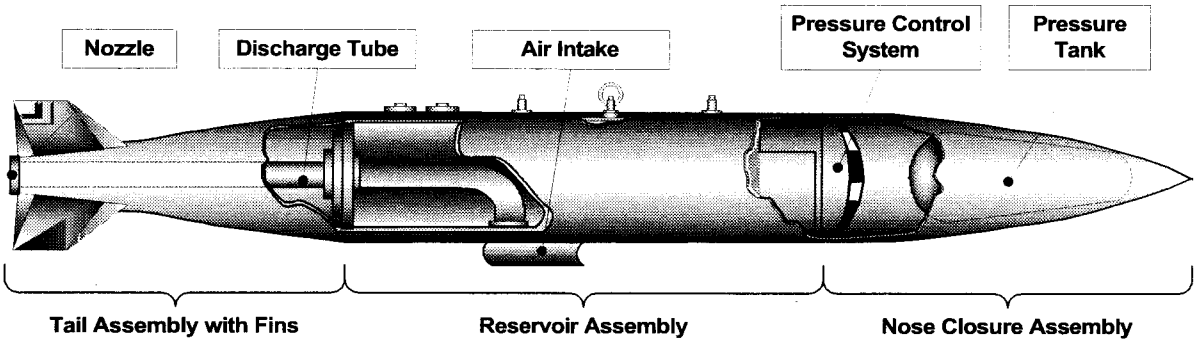


Figure 1-7. Aerial Spray Tank

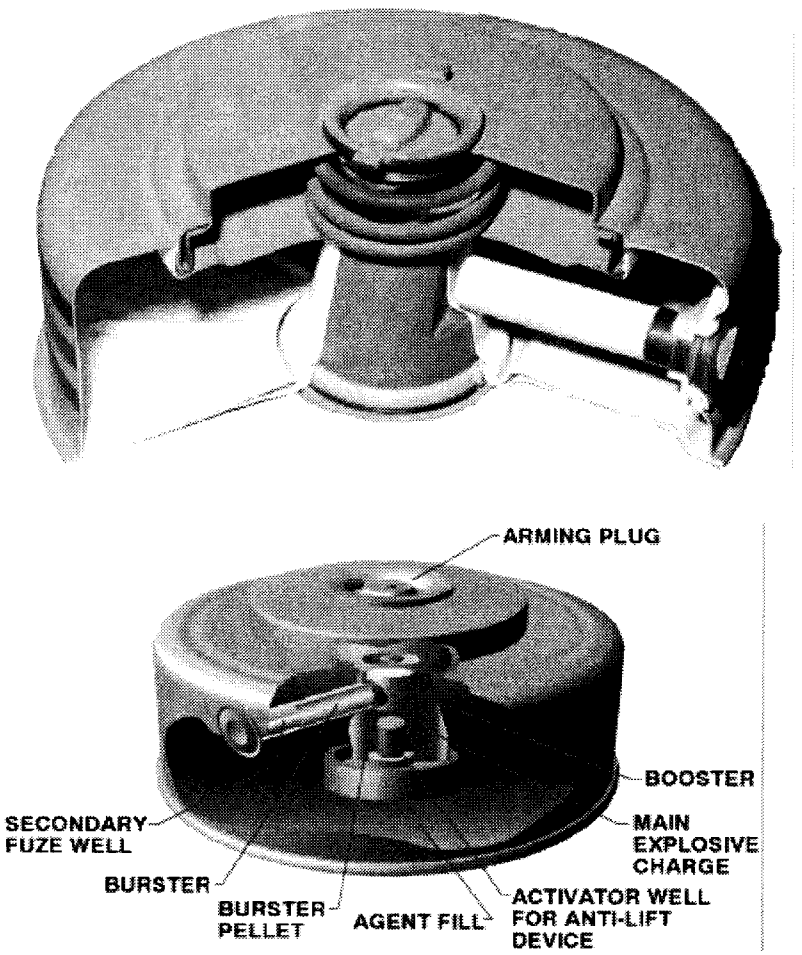
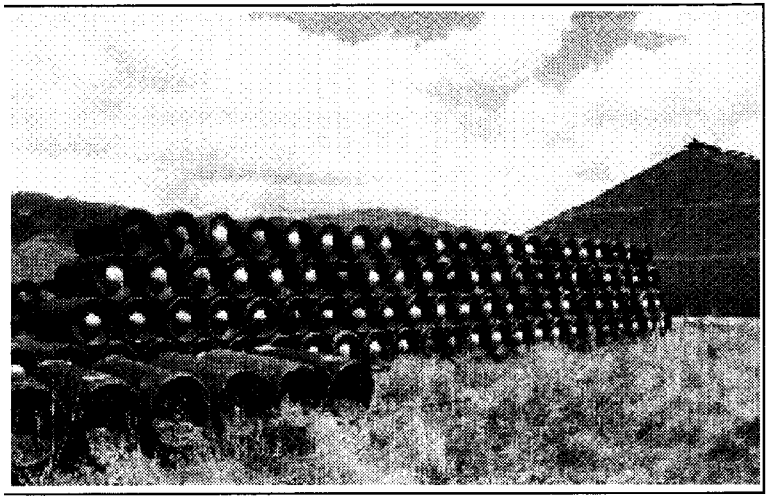
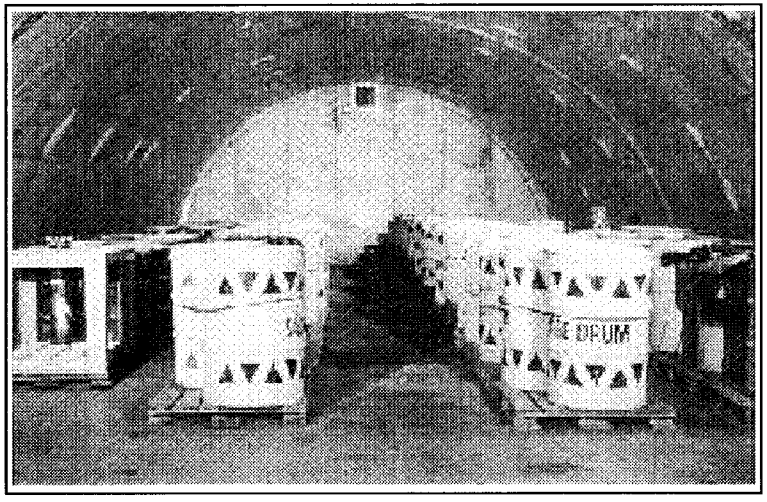


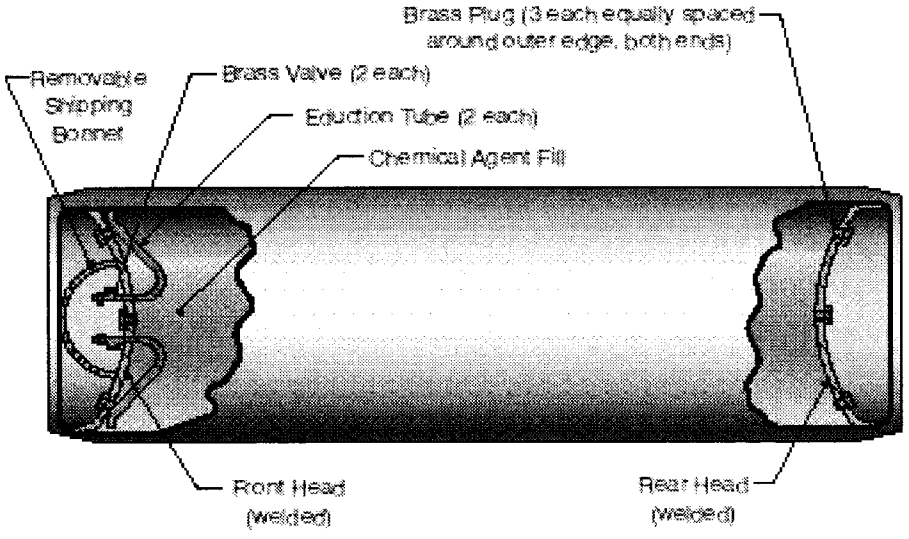
Figure 1-8. Typical Chemical Landmine



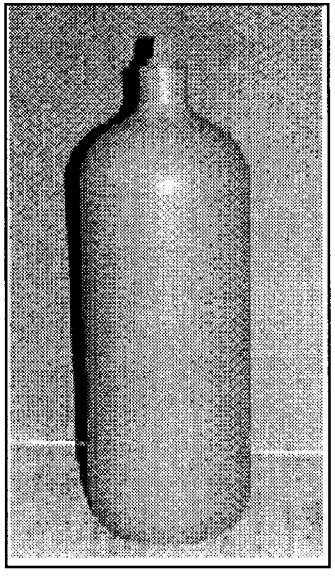
TON CONTAINERS



DRUMS IN TEMPORARY STORAGE



TON CONTAINER (bulk storage)



DEPARTMENT OF TRANSPORTATION BOTTLE

Figure 1-9. Typical Chemical Containers

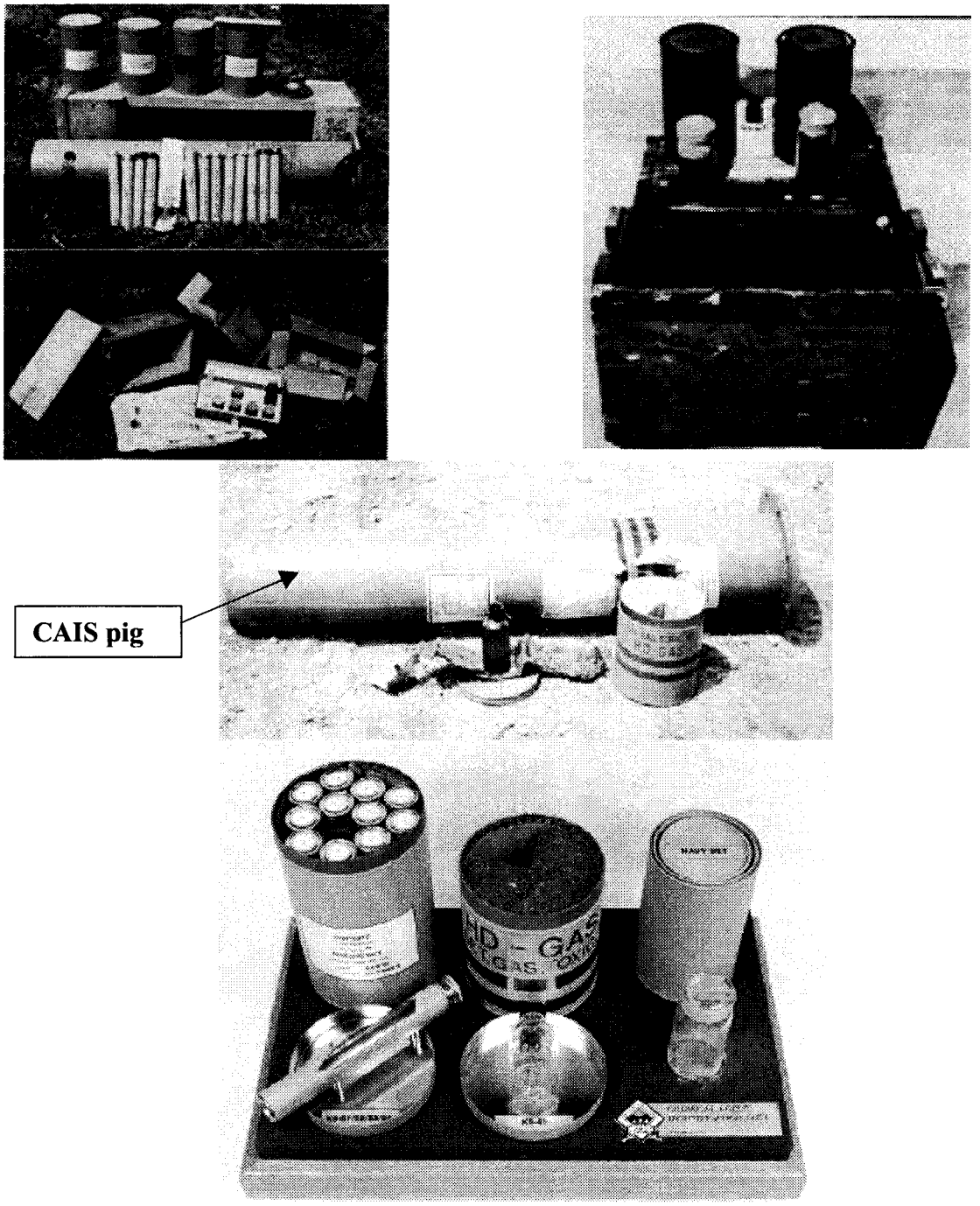


Figure 1-10. Chemical Agent Identification Sets (CAIS)

A third major variety of CAIS contained approximately 110 milliliters (3.5 ounces) of mustard agent. These sets were used for decontamination training. Terrain or equipment was purposely contaminated with mustard. The soldiers were taught how to put on the correct protective clothing and then decontaminate the area or equipment.

The chemical agent in CAIS is contained in ampoules or bottles (Figure 1-10) in small quantities. In the original CAIS, these ampoules or bottles were packaged in metal cans, which were then packaged in steel drums, wooden boxes, or heavy metal shipping containers called "pigs" (see Figure 1-10).

CAIS were expendable training items, so they were not inventoried and documented as chemical weapons. The Army made a concerted effort in the 1980s to destroy all CAIS sets that could be found. However, it is believed that many of the CAIS that were not used during training were buried in accordance with past disposal practices.

CAIS ampoules or bottles that have been recovered from burial sites to date have often been found buried outside of their original shipping containers. When shipping containers were found buried with their contents intact, the container was usually too corroded to be used for storage or transport. In most instances, the recovered ampoules or bottles were repackaged into different shipping containers that meet USDOT specifications for shipping hazardous materials. The number of bottles or ampoules packed into a shipping container varied depending on the number of CAIS items recovered at a site. Containers currently in storage hold from 1 to 48 ampoules, bottles, or a mixture of both.

1.5.2 Types of Chemicals

Chemical warfare agents, industrial chemicals, and other chemicals are the three categories of chemicals likely to be encountered in buried and store non-stockpile CWM items. Chemical warfare agents are toxic compounds that were developed and manufactured specifically to be used by the military to kill, seriously injure, or incapacitate enemy soldiers through their physiological effects.

These agents have very few, if any, other uses. Industrial chemicals are those that are manufactured for and used in normal industrial operations or research and are not developed primarily for military purposes. U.S. and foreign militaries, however, have used some industrial chemicals in chemical weapons and programs because of their chemical properties. Other chemicals could also be encountered that are not CWM, as described below.

There are 29 possible chemicals of concern that have been identified by the NSCMP based on historical research and information on weapons recovered to date (see Table 1-3). This list may not be definitive because it is possible that other chemicals could also be encountered during program implementation. However, the 29 listed chemicals are considered to be representative of the types of chemicals that could be encountered during NSCMP activities.

Table 1-3. Chemical Warfare Agents and Industrial Chemicals that Could Be Encountered in Buried and Stored Non-Stockpile Chemical Warfare Materiel

Designation	Chemical	Use	State
Chemical Warfare Agents[a,b]			
H	Levinstein mustard	Blistering agent	Oily liquid
HD	Mustard-distilled	Blistering agent	Oily liquid
HL	Mustard-lewisite mixture	Blistering agent	Oily liquid
HT	Mustard-T mixture	Blistering agent	Liquid
HN-1	Nitrogen mustard 1	Blistering agent	Oily liquid
HN-2	Nitrogen mustard 2	Blistering agent	Oily liquid
HN-3	Nitrogen mustard 3	Blistering agent	Liquid
L	Lewisite	Blistering agent	Oily liquid
GA	Tabun	Nerve agent	Liquid
GB	Sarin	Nerve agent	Liquid
GD	Soman	Nerve agent	Liquid
VX	VX	Nerve agent	Liquid
Industrial Chemicals[a,b]			
DM	Adamsite	Vomiting agent	Crystalline solid
CA or BBC	Bromobenzyl cyanide	Tearing agent	Solid or liquid
CN	Chloroacetophenone	Tearing agent	Powder
CNB	Chloroacetophenone in benzene and carbon tetrachloride	Tearing agent	Liquid
CNS	Chloroacetophenone and chloropicrin in chloroform	Tearing and vomiting agent	Liquid
PS	Chloropicrin	Tearing and vomiting agent	Oily liquid
CK	Cyanogen chloride	Blood agent	Liquid
DP	Disphosgene	Choking agent	Oily liquid
AC	Hydrogen cyanide	Blood agent	Liquid
CG	Phosgene	Choking agent	Gas
BZ	3-quinuclidinyl benzilate	Incapacitating agent	Crystalline solid
GA simulant	Ethyl malonate	Chemical agent simulant	Liquid
CG simulant	Triphosgene	Chemical agent simulant	Crystalline solid

[a]Chemical agents are sometimes mixed with chlorobenzene and nitrobenzene.

[b]Chloroform occurs as a solvent in chemical agent identification set items.

The chemicals of concern listed in Table 1-3 and the chemical agents and industrial chemicals in CAIS items are described below. Appendix E provides information on the characteristics and health hazards of the chemicals. Appendix F describes the environmental transformations of these chemicals.

1.5.2.1 Chemical Warfare Agents

Blister agents and nerve agents are the two main types of chemical warfare agents (see Table 1-3).

Blister agents work primarily by damaging skin and other tissue, although death can also result. Their main effect is to blister any exposed skin, injure eyes, and damage the respiratory tract if vapors are inhaled.

Nerve agents directly affect the nervous system and are highly toxic in both liquid and vapor form. Death from nerve agents can occur quickly, often within 10 minutes of absorbing a fatal dose.

Blister agents are expected to be the most likely type of chemical agents contained in recovered non-stockpile CWM. These agents were produced in large quantities between World Wars I and II. Items containing these agents are most likely to have been disposed of by open burning or burial. Mortar and artillery projectiles containing these agents may also be recovered as "duds" from test and firing ranges.

Nerve agents are much less likely to be encountered in non-stockpile CWM. Nerve agents were produced only after World War II and were subject to strict inventory controls. By the time munitions filled with nerve agents were produced, disposal practices had changed and burying chemical weapons was no longer practiced. Artillery, mortar, and other projectiles filled with nerve agents may be recovered as duds from a small number of firing ranges.

1.5.2.2 Industrial Chemicals

Industrial chemicals are chemicals that were manufactured for use in normal industrial operations or research and were not developed only for military purposes, as were chemical agents. The military, however, has used industrial chemicals in chemical warfare weapons and programs because of their chemical properties (see Table 1-3). Some chemicals have been weaponized because they are toxic or because they cause injuries or incapacitation.

Other chemicals have been used in training to simulate chemical agents or have been mixed or used with chemical agents in chemical munitions or in the testing of chemical munitions.

1.5.2.3 Chemicals in Chemical Agent Identification Sets

The purpose of CAIS was to train soldiers to identify chemical agents in the field. CAIS were not produced to kill, seriously injure, or incapacitate enemy soldiers through physiological effects, as were chemical warfare agents and industrial chemicals in chemical munitions. Most CAIS contain small quantities of blistering agents in diluted form, industrial

chemicals, and agent stimulants. CAIS do not contain nerve agent. Table 1-4 shows the types of CAIS and the types and quantities of chemicals each contains.

CAIS items that contain chemical agent are CWM under federal law. CAIS items that contain only industrial chemicals are not CWM.

1.5.2.4 Other Chemicals

Some munitions or containers may be recovered during non-stockpile CWM activities that contain chemicals that are not non-stockpile CWM, but which could be misidentified initially in the field as non-stockpile CWM. Some of the chemicals and items that could be misidentified are various smoke mixtures, furfural, and white phosphorous. These chemicals are not managed or disposed of by the NSCMP and will not be processed and treated by the transportable treatment systems. When the contents of these munitions or containers have been properly identified, they will be turned over to the appropriate authority for disposal.

1.5.3 Status of Non-Stockpile Chemical Materiel

Non-stockpile CWM is categorized by the NSCMP as (1) buried CWM, (2) recovered CWM, or (3) miscellaneous CWM.

1.5.3.1 Buried Chemical Materiel

According to available records, CWM was disposed of by land burial until the late 1950s, which was considered an acceptable practice until that time. Types of CWM buried included chemical munitions, containers of chemical agent, and CAIS. In most cases, the CWM was burned or chemically neutralized before it was buried.

Before disposal, chemical munitions were typically stored or handled in the safest configuration allowable. Large munitions, if filled with chemical agent, were usually stored without explosive charges (bursters) and fuzes (the detonation devices for setting off the burster), making them non-explosively configured. Smaller munitions were stored with bursters and fuzes installed.

When stored munitions were disposed of by burial, bursters (if present) may have been removed if it was safe to do so. This was done to prevent accidental detonation during burial operations.

Buried munitions also include munitions that were fired or dropped on test ranges but which failed to detonate. These munitions would most likely contain both bursters and fuzes.

There are a number of burial sites located on military installations that are known to or are suspected to contain CWM. In some cases, CWM may be buried on formerly used defense sites (FUDS), which are no longer controlled by the DoD.

Table 1-4. Components of Chemical Agent Identification Sets

Type	Bottles or Ampoules per set	Chemical	Amount per Bottle or Ampoule	Amount of Chemical per set
K941	24	Levinstein mustard (H), distilled mustard (HD), or sulfur mustard (HS)	103.3 milliliters	2,480 milliliters
K942	28	Mustard (H), distilled mustard (HD), or sulfur mustard (HS)	112.5 milliliters	3,150 milliliters
K951 and K952	12	Mustard (H)	2 milliliters[b]	24 milliliters
	12	Lewisite (L)	2 milliliters[b]	24 milliliters
	12	Chloropicrin (PS)	20 milliliters[c]	240 milliliters
	12	Phosgene (CG)	40 milliliters	480 milliliters
K953 and K954	8	Mustard (H)	2 milliliters[b]	16 milliliters
	8	Nitrogen mustard (HN-1)	4 milliliters[d]	32 milliliters
	8	Lewisite (L)	2 milliliters[b]	16 milliliters
	8	Phosgene (CG)	40 milliliters	320 milliliters
	8	Cyanogen chloride (CK)	40 milliliters	320 milliliters
	8	Ethyl malonate (GA simulant)	40 milliliters	320 milliliters
K955	2	Sulfur mustard (HS)	25 milliliters[e]	50 milliliters
	1	Lewisite (L)	25 milliliters[e]	25 milliliters
	1	Chloropicrin (PS)	25 milliliters[e]	25 milliliters
	1	Triphosgene (CG simulant)	6 grams	6 grams
	1	Chloroacetophenone (CN)	15 grams	15 grams
	1	Adamsite (DM)	15 grams	15 grams
X302	1	Nitrogen mustard (HN-1)	25 milliliters	25 milliliters
	1	Nitrogen mustard (HN-3)	25 milliliters[e]	25 milliliters
X545	2	Triphosgene (CG simulant)	3 grams	6 grams
X546	2	Chloroacetophenone (CN)	15 grams	30 grams
X547	2	Sulfur mustard (HS)	25 milliliters[e]	50 milliliters
X548	2	Lewisite (L)	25 milliliters[e]	50 milliliters
X549	2	Adamsite (DM)	15 grams	30 grams
X550	2	Nitrogen mustard (HN-1)	25 milliliters[e]	50 milliliters
X551	2	Nitrogen mustard (HN-3)	25 milliliters[e]	50 milliliters
X552	2	Chloropicrin (PS)	25 milliliters[e]	50 milliliters

[a] Source: Department of the Army, 1995.

[b] In solution with 38 milliliters of chloroform

[c] In solution with 20 milliliters of chloroform.

[d] In solution with 36 milliliters of chloroform.

[e] Absorbed onto 90 cubic centimeters of activated charcoal.

Note: 1 ounce equals approximately 29.6 milliliters or 28.4 grams.

As of 1996, the NSCMP had identified 168 possible burial sites that may contain buried CWM in 38 states and territories. DoD has also determined that 56 additional burial sites require no further action (for example, no buried CWM was discovered during site investigation or the buried CWM has been removed) (Department of the Army, 1996a). Additional CWM burial sites could be discovered in the future.

Research and onsite investigations are continuing in order to obtain more definitive information on those burial sites that have been identified. Currently, it is highly uncertain as to the number of possible burial sites that may actually contain CWM, the quantities and types of buried CWM that may be present, and what actions should be taken to protect human health, safety, and the environment.

The NSCMP has categorized CWM burial sites into four types. These are sites only containing CAIS, small-quantity non-explosive burial sites, small-quantity explosive burial sites, and large-quantity burial sites (Table 1-5).

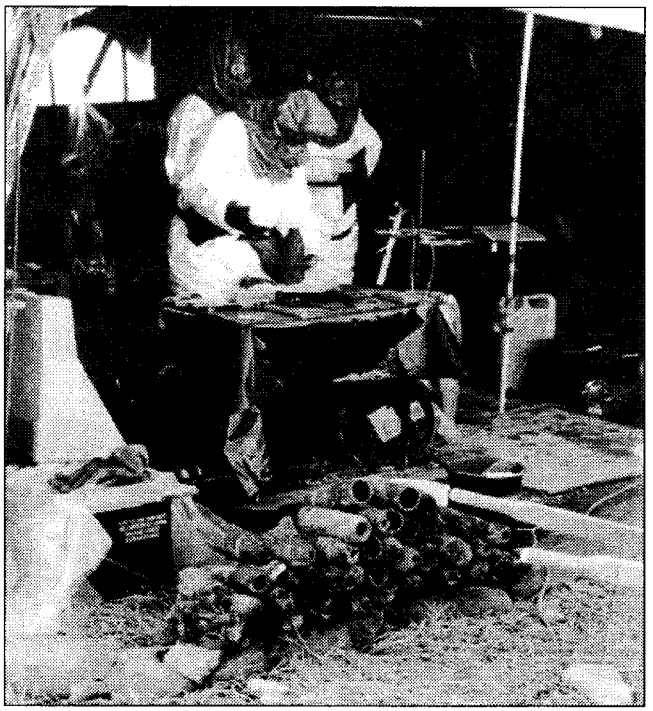
1.5.3.2 Recovered Chemical Materiel

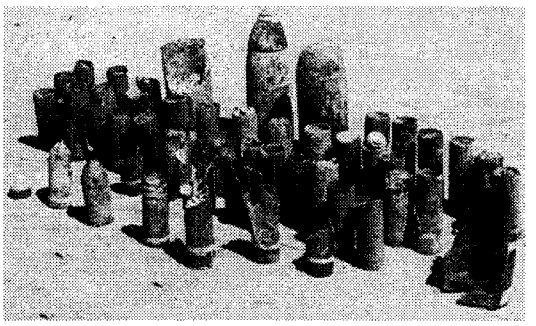
Recovered CWM (Figure 1-11) items are those that have been placed in storage after recovery from firing and test ranges and from burial sites. Currently nine military installations are storing non-stockpile CWM items. Eight of these nine installations also have burial sites. Recovered CWM currently being stored includes CAIS items, chemical munitions without explosive components, chemical munitions with explosive components, and bulk items.

Table 1-5. Types of Chemical Warfare Materiel Burial Sites

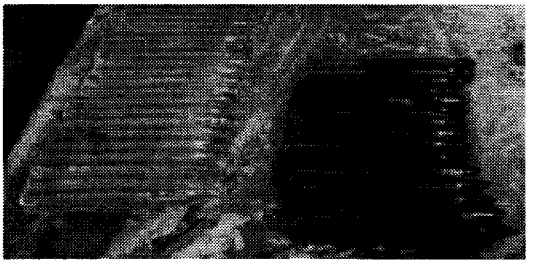
Type of Burial Site	Content of Site
CAIS	CAIS items only.
Small-quantity non-explosive sites	Potential to contain less than 1,000 CWM items. No potential for chemical munitions with explosive components or propellants. Could also contain containers of chemical agent and CAIS items.
Small-quantity explosive sites	Potential to contain less than 1,000 CWM items. Potential for chemical munitions with explosive components or propellants.
Large-quantity sites	Potential for more than 1,000 CWM items. Could contain all types of CWM.

CAIS – chemical agent identification set
CWM – chemical warfare materiel





Munitions



CAIS Ampoules

Figure 1-11. Recovery Operations and Recovered Non-Stockpile Chemical Warfare Materiel

1.5.3.3 Miscellaneous Chemical Materiel

The miscellaneous category of chemical warfare materiel includes chemical samples. Chemical samples are chemical agents that were transferred from leaking and tested recovered and stockpiled munitions to glass ampoules, metal cylinders, and one-ton containers. The agent was transferred to facilitate safe storage, assess the quality of the chemical agent, or ascertain the causes and seriousness of leaking munitions. These samples are currently in storage. Some of these chemical samples may be re-designated as research, development, test, and evaluation materiel and will be consumed in future research programs.

1.6 Limitations on Moving Non-Stockpile Chemical Materiel

The U.S. Congress has passed legislation that places limits and restrictions on the movement of chemical munitions and agents. In general, these laws specify where chemical munitions or agent can be taken and the conditions that must be met in order for the movement to take place.

Public Law 91-121, enacted in 1969, requires the DoD to implement the following actions before transporting any lethal chemical agent to or from any military installations in the United States:

- The Secretary of Defense must determine that the proposed transportation is necessary in the interest of national security.
- The Secretary of Defense must bring the particulars of the proposed transportation to the attention of the Secretary of the Department of Health and Human Services.
- The Secretary of Defense must implement any precautionary measures recommended by the Secretary of the Department of Health and Human Services.
- The Secretary of Defense must provide notification to Congress at least 10 days prior to any such transportation and to the appropriate Governors of the states through which any such agents will be transported in advance of such transportation.
- In the event that the Secretary of Defense finds that the recommendations of the Secretary of the Department of Health and Human Services would have the effect of preventing the proposed transportation, the President may determine that overriding considerations of national security require such transportation to be conducted. In this case, the President must provide notification to Congress as far in advance as practical.

A provision in Public Law 91-441, enacted in 1970, provides an exemption to the above review and reporting requirements for chemical munitions or agents that constitute an emergency threat to public health and safety. This exemption allows any such chemical munitions and agents to be disposed of immediately, including any necessary transportation, without prior review and reporting requirements.

The National Defense Authorization Act for Fiscal Year 1995 (Public Law 103-337) placed additional restrictions on the moving of chemical munitions and agents. These restrictions prevent moving non-stockpile CWM out of the state where it is located, unless it is being moved to the nearest CWM stockpile storage facility that has permits for receiving and storing such munitions and agents. The Secretary of Defense must consider the movement of non-stockpile CWM necessary, and such movement can only take place if public health and safety is protected adequately during the transportation.

1.7 RCRA and CERCLA Regulation of Transportable Treatment Systems

RCRA and CERCLA are the primary statutes under which treatment of non-stockpile CWM are regulated. These statutes are described below. Other applicable regulations are described in Section 4.

Using a transportable chemical treatment system to treat non-stockpile CWM would occur under the requirements of CERCLA at some sites and under the requirements of RCRA at other sites (and in some cases under a combination of the two programs). The program (RCRA or CERCLA) that applies at a specific treatment location could depend on the complex interaction of a variety of factors specific to that site. Factors considered in determining which program applies include the following: the program under which the

CWM was originally recovered, whether the CWM is being treated at the site at which it was originally recovered or whether it has been moved off the recovery site, and the existing status of the recovery site with regard to RCRA and CERCLA. (A discussion of how just several of the relevant factors can interact in selecting between the two programs is presented in 54 Federal Register [FR] 10520-10526.)

Regardless of which program applies, the end result of the response action should be essentially the same; generally, only the procedures for arriving at the end result differ. The U.S. Environmental Protection Agency (USEPA) has, in fact, indicated that it is its "expectation that remedies selected and implemented under CERCLA will generally satisfy the RCRA corrective action requirements and vice versa" (52 FR 17993, 52 FR 27645, and 54 FR 10523).

Since the RCRA and CERCLA programs are referred to repeatedly throughout this environmental impact statement, this section provides an overview of each program and its requirements. The discussion focuses only on the portions of each program applicable to the treatment of CWM in the four transportable treatment systems. More detail is provided in Section 4.6.

1.7.1 Resource Conservation and Recovery Act

The *Resource Conservation and Recovery Act of 1976*, as amended, (42 U.S. Code [USC] 6901 et seq.) was enacted to ensure the safe and environmentally responsible management of hazardous and non-hazardous solid waste, and to promote resource recovery techniques to minimize waste volumes. Regulations issued by the USEPA pursuant to RCRA set forth a comprehensive national program to provide "cradle-to-grave" control of hazardous waste by requiring generators and transporters of hazardous waste and owners and operators of hazardous waste treatment, storage, and disposal facilities (TSDFs) to meet specific standards and procedures. Under RCRA, the USEPA may authorize individual states to administer and enforce hazardous waste programs that are at least as stringent as the federal program. The use of transportable treatment systems to treat CWM at a specific site and the offsite transport of recovered CWM would, when conducted under the RCRA program, be subject to the RCRA standards and procedures. This includes the requirement discussed below for the transportable treatment system to obtain a RCRA permit before being set up and used at a specific treatment site. Public comment and input are required before the permit can be issued.

A ***solid waste*** under RCRA is a solid, liquid, semi-solid, or contained gaseous material that is discarded (either by being abandoned or recycled as defined in 40 CFR 261.2), with certain exclusions. None of these exclusions apply to the CWM considered in this environmental impact statement. Once discarded the material remains a RCRA solid waste regardless of whether it is subsequently used, reused, recycled, reclaimed, discarded again, or stored or accumulated for any of the five preceding purposes.

The RCRA regulations (at 40 CFR 261) identify those solid wastes that are to be managed as hazardous waste subject to RCRA. ***Hazardous waste*** is defined as any solid waste that is

not specifically excluded from regulation (none of the specified exclusions apply to the CWM considered in this environmental impact statement) and that meets one or more of the following criteria:

- The waste exhibits the characteristics of ignitability, corrosivity, reactivity, or toxicity as defined in the RCRA regulations.
- The waste is specifically listed as hazardous waste under the RCRA regulations.
- The waste is a mixture of a solid waste and a listed hazardous waste (with certain exceptions).
- The waste is generated (that is, derived) from the treatment, storage, or disposal of hazardous waste (with certain exceptions).

No chemical warfare agents are included in the federal list of hazardous waste (second bullet above), although several of the industrial chemicals that may be present in CWM are listed. Several states that have been authorized by the USEPA to administer and enforce the RCRA hazardous waste program have added various chemical agents to their lists of hazardous waste (and in some cases have also listed residues from the treatment of the listed chemical agents as hazardous waste).

The Army intends to manage all CWM and neutralent wastes considered in this environmental impact statement as a hazardous waste even if some of it does not meet the above definition of a hazardous waste.

Under RCRA and authorized state RCRA programs, constructing and operating a hazardous waste TSDF requires a permit. A transportable treatment system would be considered a TSDF under RCRA. (In the case of a transportable treatment system, construction refers to the setup of the system at the site, not the actual construction of the treatment system itself.)

When a permit is required, the facility may not be constructed, modified, operated, or accept hazardous waste without a permit. The permit is intended to ensure that the hazardous waste TSDF is constructed and operated in accordance with RCRA regulations. The permit specifies all of the particular conditions that apply to the facility, including the specific hazardous wastes it can manage, the specific RCRA regulations with which it must comply, whether the facility can receive waste from offsite or from out-of-state, and the expiration date of the permit.

In addition to a RCRA permit, hazardous waste facilities must comply with two types of standards: (1) general standards applicable to all hazardous waste facilities and (2) facility specific standards applicable to specific types of treatment, storage, and disposal units at a facility (e.g., landfill, storage containers, various treatment units). General standards contain requirements for siting of hazardous waste facilities and for security, inspections, waste analysis, training, preparedness and prevention, contingency plans and emergency preparedness, and facility closure. Facility-specific standards include requirements for designing, operating, and

locating the treatment, storage, or disposal unit as well as for monitoring and detecting releases from the unit, for responding to any such releases, and for closure of the unit.

The four transportable treatment systems would be considered miscellaneous units under RCRA and would be subject to the RCRA standards for miscellaneous units (40 CFR 264 Subpart X) as well as to the general standards. These requirements are discussed in more detail in Section 4.6. That chapter also discusses the additional federal, tribal, state, and military regulations that could also apply.

Treating CWM in the transportable treatment systems would generate various solid wastes, some of which would be hazardous waste as discussed above. Chapter 3 identifies the different wastes that would be generated and the type of facility where each would be managed. All hazardous wastes, plus certain additional wastes identified in Chapter 3, would be sent to a hazardous waste TSDF for management (treatment, storage, and/or disposal).

Managing the waste at a hazardous waste TSDF would be carried out in accordance with the RCRA requirements discussed above, as well as with RCRA land disposal restrictions (LDRs) under 40 CFR 268. The LDRs identify those hazardous wastes restricted from land disposal and define the limited circumstances under which an otherwise prohibited waste may be land disposed. Such disposal generally requires that the waste first be treated to meet the standards specified in 40 CFR 268. Applicable LDRs are discussed in more detail in Chapter 4.

1.7.2 Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA, as amended, (42 USC 9601 et seq.) provides for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and for the cleanup of inactive hazardous waste disposal sites. Releases addressed by CERCLA include past, present, and potential future releases of almost any substance, compound, or mixture that could cause an adverse human health or environmental impact. Based on the definitions in CERCLA, CERCLA releases can include the past burial of CWM.

CERCLA response requirements and procedures are implemented by the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300), also known as the National Contingency Plan (NCP). CERCLA, in conjunction with the NCP, identifies and defines roles for USEPA, states, and federal agencies, such as DoD (and its components), in the response process.

CERCLA provides for two types of responses to releases: removal actions and remedial actions. Removal actions consist of short-term limited actions taken to respond to a problem, which may include an emergency situation. A removal action, for example, might consist of erecting a fence to limit access to a site, storage of recovered hazardous substances, and/or treatment of recovered hazardous substances. Remedial actions consist of longer-term actions directed to providing a final permanent remedy to the problem. This may include actions directed at restoring contaminated media (that is, soil, groundwater, and surface water), as well

as the treatment of contaminated media and hazardous materials (such as buried CWM) recovered from the CERCLA site. Depending upon site-specific conditions, a site may require both removal and remedial actions. The NCP (at 40 CFR 300.410–300.435) specifies the process by which the remedial and/or removal actions to be undertaken at any specific site are to be selected and carried out, including requirements for public involvement in the process.

If a transportable treatment system were to be used in a response action on a CERCLA site, it could be brought to the site either as part of a planned CERCLA response action at the site or in response to the accidental discovery of buried CWM at the site. The use of the transportable treatment system could be the major component of the response action at the site or just one small component among many parts of the response action. For example, the response action could involve excavating buried CWM and other hazardous substances from the site, treating the recovered CWM with a transportable treatment system, treating other recovered hazardous substances with other types of treatment systems, and restoring the contaminated soil, groundwater, and/or surface water at the site. As discussed in Sections 1.8 through 1.10, only that portion of the response action that directly involves the transportable treatment system is the subject of this environmental impact statement. All other portions of the response action, including recovering buried CWM and any subsequent remediation of the burial site other than the recovered CWM items, are not the subject of this environmental impact statement.

The requirements that a transportable treatment system would have to comply with, when used in a CERCLA response action on a CERCLA site, would be specified as part of the remedy selection process for the site. The requirements would be based on federal and state environmental laws and regulations that are determined to be either *applicable* or *relevant and appropriate requirements* (ARARs).

Almost any substantive requirement pursuant to federal or state environmental statutes can be designated as an ARAR. Substantive requirements are defined as those requirements that pertain directly to actions (such as the use of a transportable treatment system) or to conditions in the environment (such as the concentration of contaminants in water, soil, or air) (U.S. Environmental Protection Agency, 1992a)—for example, substantive requirements include performance standards for a treatment technology (such as a transportable treatment system) or standards for acceptable concentrations of contaminants in groundwater or surface water (with regard to the remediation of the site media). CERCLA mandates that no federal, state, or local permit shall be required for the portion of any removal or remedial action conducted entirely on the CERCLA site, providing such remedial action is selected and carried out in compliance with CERCLA requirements.

The ARARs that would be applied to a transportable treatment system used on a specific CERCLA site would be determined as part of the remedy selection process for that site. One principal ARAR that would be applied would be the substantive requirements of RCRA; however, a RCRA permit would not be needed. RCRA requirements are discussed above.

It should be noted that the CERCLA requirement to comply with ARARs applies only to on-site actions under CERCLA. If buried CWM was to be recovered under a CERCLA action but then transported to a transportable treatment system located off the CERCLA site, the use of the transportable treatment system would be subject to RCRA regulations and all other applicable laws and regulations, not to CERCLA requirements. These laws and regulations are, however, the basis for developing the applicable requirements of the CERCLA ARARs in the first place.

The term on-site as used in this environmental impact statement may differ from the CERCLA definition of on-site at some sites. For the environmental impact statement, on-site means the entire area within the boundaries of a military installation or private property where the CWM item is located. For CERCLA, the NCP (at 40 CFR 300.5) defines on-site to mean "the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action." At some facilities, the CERCLA on-site area has been declared to be the entire area within the facility boundaries, while at other facilities it encompasses just a small portion of the entire facility. This is a site-specific determination made as part of the remedy selection process.

For CERCLA responses, as long as the management of buried CWM remains within the CERCLA-designated on-site area after recovery, management of the recovered CWM is considered to be on-site and remains subject to CERCLA. However, if the recovered CWM is subsequently transported off of the designated on-site area, its management, starting at that point in time, is considered to be off-site and is no longer subject to CERCLA, but rather becomes subject to all other applicable laws and regulations as discussed above. The management is considered to be off-site even when it occurs elsewhere within the boundary of the same installation, but outside of the designated CERCLA on-site area. The extent of the on-site area is determined as part of the CERCLA response process.

1.8 Organizational Responsibility for Buried and Recovered Non-Stockpile Chemical Warfare Materiel

The responsibility for managing, processing, and treating buried and recovered CWM is divided among several DoD organizations. In general, managing CWM burial sites and stored (recovered) CWM is the responsibility of the military installations or the U.S. Army Corps of Engineers. The NSCMP is responsible for processing and treating CWM when the decision has been made that items in burial sites or storage must be destroyed, and the items are presented to the NSCMP for treatment and processing. Figure 1-12 shows the CWM management activities and the organizations responsible for each.

1.8.1 Materiel Burial, Recovery, and Storage Sites

Management or remediation of burial and storage sites where CWM is found and recovered is the responsibility of the military installation or the U.S. Army Corps of Engineers depending

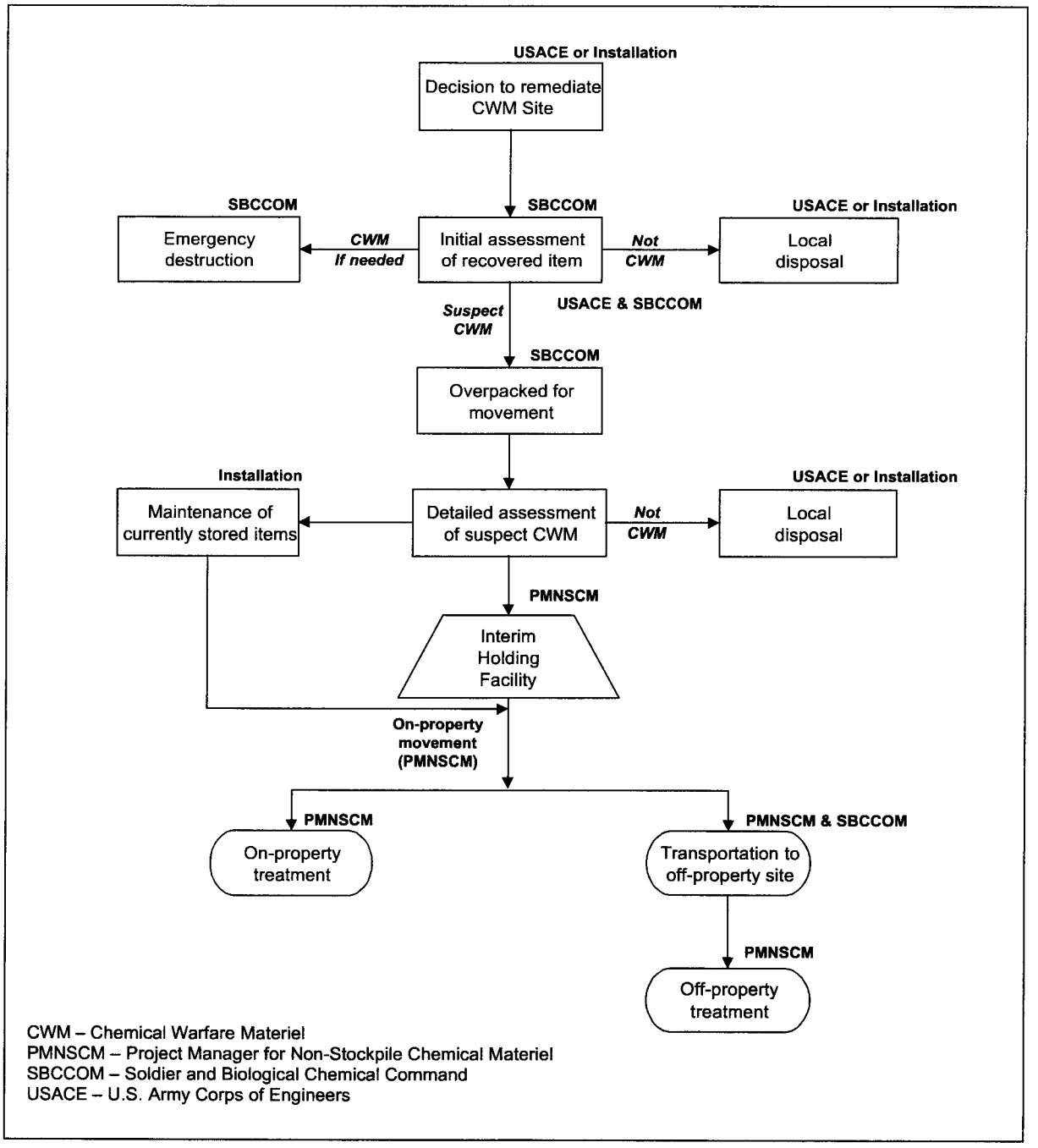


Figure 1-12. Organizational Responsibility for Buried and Recovered Non-Stockpile Chemical Warfare Materiel

on the location of the site. Advice and guidance is provided by NSCMP. If the burial or recovery site is an active military installation, the installation command can maintain management responsibility or can turn over responsibility to the U.S. Army Corps of Engineers. If the burial or recovery site is on a formerly used defense site no longer controlled by the DoD, the Army Corps of Engineers is the responsible manager. The NSCMP can provide advice as requested by the military installation or U.S. Army Corps of Engineers.

The responsibility for recovered CWM items placed in storage depends on the storage location. Items placed in an existing facility on an active military installation are the responsibility of the installation command or the U.S. Army Corps of Engineers. Items placed in an Interim Holding Facility (see Section 2.5) become the responsibility of the NSCMP.

1.8.2 Materiel Processing, Treatment, and Disposal

CWM becomes the responsibility of the NSCMP when a recovered item is brought to the treatment system location.

1.9 Activities at Non-Stockpile Burial, Recovery, and Storage Locations Before Processing and Treating Chemical Warfare Materiel

A number of activities involving buried and recovered CWM take place prior to treating CWM in transportable treatment systems. These activities are not part of the NSCMP and are the responsibility of other DoD organizations (Section 1.8) that conduct the activities under the requirements of CERCLA and/or RCRA (Section 1.7). Figure 1-12 shows the activities that would occur prior to treating non-stockpile CWM in the transportable chemical treatment systems or storing of non-stockpile CWM pending the development and availability of other treatment systems. These activities would be implemented on a site -specific basis. These activities would be conducted in accordance with all applicable federal, tribal, state, and local laws and requirements, as well as the appropriate military service's regulations. The activities are described below.

1.9.1 Recovery

Operations involving the recovery of buried CWM could occur either as part of the planned cleanup of burial sites conducted either in accordance with the requirements of CERCLA, RCRA, and similar state laws or when CWM is accidentally discovered. Reviews of historical information would be conducted as part of the decision process to help determine the possible types of CWM that may have been disposed of at the site. Prior to undertaking cleanup actions at a burial site that may contain CWM, the U.S. Army Corps of Engineers at formerly used defense sites, or the host installation at active installations would prepare work plans and site safety submissions detailing the recovery operations to be undertaken. Generally, the Army Corps of Engineers or an installation contractor would locate and unearth the buried CWM.

Accidental discoveries of buried CWM would generally be made during activities involving excavation when an unexploded ordnance item, or unidentified container, is unearthed in an area not known to have been previously used for disposal. If the item is suspected of being military in origin, first responders would normally request assistance from a local military explosive ordnance disposal unit. If the explosive ordnance disposal team, all of whom receive CWM recognition training, suspects the discovered item is a CWM item, the explosive ordnance disposal team would report the incident to the Army Operations Center and to the U.S. Army Corps of Engineers if the discovery is not on an active installation. U.S. Army Technical Escort Unit personnel would then be dispatched to assist in determining whether the item(s) are CWM and, if so, would recover the item(s).

1.9.2 Initial Identification and Safety Assessment

When suspected CWM items are recovered, Technical Escort Unit or explosive ordnance disposal personnel perform initial identification of such items. The NSCMP has published a document (SciTech, 1998) to assist these personnel in identifying CWM items and to aid decision-makers on methods of munition handling and disposal. This document provides information regarding design, markings, and potential hazardous fills of non-stockpile CWM.

The first step in the identification process is to determine if a suspected recovered CWM item is military in origin and whether the item is safe to handle. If the item is safe to handle, a more thorough inspection of the item is conducted to determine whether or not the item is leaking, structurally sound, and whether or not explosive components are present. If the more thorough inspection indicates that the item is leaking, it is sealed using prescribed procedures.

If Technical Escort Unit or explosive ordnance disposal personnel determine that a recovered non-stockpile CWM munition is not safe to handle (for example, if it has an armed fuze that may cause an unplanned detonation), an attempt would be made to render the munition safe. The render-safe procedures to be used are specific to each munition and fuze combination. After render-safe procedures are successful, the CWM munition would be further identified as described above.

Immediate emergency destruction may be required if personnel determine that no render-safe procedures can be done or that the munition would still not be s afe to store after performing the procedures. Immediate emergency destruction would generally involve the placing of high explosives on an unsafe item in a ratio of 5 pounds of explosive for each pound of chemical agent in the item to be destroyed. Detonation destroys the item and the agent. Prior to the emergency destruction of a CWM item, site-specific emergency destruction plans would be prepared and approved. Emergency destruction would not be delayed pending approval of site-specific emergency destruction plans if there were an imminent danger to the public or the environment.

The Explosive Destruction System (EDS), described in Section 2, could also be brought to the site and used for the destruction of the unsafe item if it is determined that the item can

be handled enough to be loaded into the system. It is anticipated that building the EDS could reduce, but perhaps not eliminate, the need for open emergency destruction of some recovered CWM.

1.9.3 Additional Identification and Assessment

Additional assessment of items would be carried out after the initial field investigations described above. This is done because identification of non-stockpile CWM items using conservative field methods may lead to identifying items as being CWM (i.e., suspect CWM) when they actually are not CWM.

The NSCMP currently uses several nondestructive and nonintrusive assessment techniques to conduct additional assessment of the type of chemical fills that may be contained in recovered non-stockpile CWM items. For example, a Raman spectroscopy system could be used to identify chemicals in CAIS items as part of the Rapid Response System (RRS) described in Section 2.1 and Appendix C, and radiography (X-ray) and portable isotopic neutron spectroscopy systems have been incorporated into the Phase I Mobile Munitions Assessment System (MMAS) for identifying chemical fills in munitions or bulk containers. The Phase I MMAS, is now being used by the U.S. Army Technical Escort Unit. Currently the NSCMP is also developing a Phase II MMAS.

The identification process for recovered non-stockpile CWM is complex and is important to all subsequent activities for non-stockpile CWM. A Munitions Assessment Review Board manages the identification process. This board is chaired by the Commander of the U.S. Army Technical Escort Unit. Board membership comprises (1) three explosive ordnance disposal technicians, of whom two must be master explosive ordnance disposal technicians; (2) a certified radiographer (X-ray technician); (3) a portable isotopic neutron spectroscopy expert; (4) a chemical specialist; (5) a representative of the Product Manager for Non-Stockpile Chemical Materiel; and (6) a historian from the Soldier and Biological Chemical Command. Representatives from an affected installation are voting members for items under their jurisdiction and additional representatives with specialized expertise may be invited by the Chairperson of the Board. The purpose of the Munitions Assessment Review Board is to assess and evaluate information used to nondestructively investigate each munition to ensure that munitions are not prematurely dismissed from the storage, handling, and treatment processes for chemical-agent-filled munitions. The Munitions Assessment Review Board can require specific munitions to be reassessed after reviewing the identification and assessment information on each munition.

Many of the suspected CWM items that are currently being stored were recovered and stored prior to the development of nondestructive identification techniques. Reassessment of items currently stored as non-stockpile CWM items could lead to a reclassification of some of the items. It might be determined that these are not non-stockpile CWM items. Suspected non-stockpile CWM items currently in storage are being reassessed using the newly developed

techniques. The reassessment of suspected CWM items currently in storage could involve each of the same activities as previously described for newly recovered CWM items.

1.9.4 Packaging

Suspect CWM items are packaged in several ways. An example is sealing the item in a plastic bag or plastic sheeting, placing the item in a metal container (overpack), and adding vermiculite or other cushioning material around the sealed item in the container until the container is full. Casting materials, such as plaster of Paris bandages wrapped around the item, could be used to provide additional strength if the structural integrity of an item is not strong enough to sustain transport without damage (Department of the Army, 1990).

Several types of metal containers, or overpacks, have been used for previously recovered items. These include (1) empty propellant charge cans previously used to ship and store propellant for firing artillery projectiles, which are sealed with a metal lid and rubber gasket; (2) empty CAIS shipping containers, or pigs, which are metal cylinders closed with a lid that is bolted on using a lead or rubber gasket; and (3) single-round containers. Recently the NSCMP has developed Army-approved containers, as described in chapter 2, which have a machined flange and lid with an o-ring seal. Single-round containers and Army-approved containers have been designed to (1) meet general USDOT requirements for transport of CWM items, (2) provide long-term storage capability, and (3) allow for transport of CWM items by air. In most cases, only one CWM item would be packaged into an individual container.

1.9.5 Movement to Storage

Once a recovered CWM item has been overpacked, the overpacked item would then be moved to a storage facility. Movement of packaged items between the site of recovery and an on-property storage facility would be accomplished using hand carts, dollies, forklifts or open bed trucks (for example, flat bed or pick-up trucks). Movement of overpacked non -stockpile CWM items would be escorted by security personnel. Emergency response personnel would have response equipment readily available. (Department of the Army, 1993a) All pending movement of non-stockpile CWM would be evaluated for potential risks in site-specific plans. The site-specific plans would include the evaluation of hazard control measures and contingency actions, as appropriate. All site-specific plans would require approval prior to the on-property movement of non-stockpile CWM items.

1.9.6 Short-Term Storage

In most instances, it is expected that some form of interim storage of overpacked non-stockpile CWM items would be required during the recovery activity and would occur regardless of whether transportable chemical treatment systems are available and operational at recovery locations. As described in Section 2.5, the Army has purchased portable interim holding facilities (IHFs) for the storage of non-stockpile CWM items at sites without appropriate existing

storage facilities. At some non-stockpile CWM sites, existing ammunition magazines and igloos have been and can be modified for the interim storage of non-stockpile CWM items.

Prior to the interim storage of non-stockpile CWM items, a storage plan would be prepared that would be based in part on the potential risks of storing non-stockpile CWM items onsite. The storage plan, would consider both the duration of storage and the quantities of non-stockpile CWM items to be stored. Depending on site-specific circumstances and the approval of the storage plan, interim storage facilities that would be used initially to store recovered non-stockpile CWM items, could be used for longer-term storage.

Any such storage would have to be approved and conducted in accordance with applicable RCRA and/or CERCLA requirements, as discussed in Sections 1.7 and 4.6.

1.9.7 Long-Term Storage

CWM items may have to be placed in long-term storage to await the availability of treatment and disposal systems. The location of long-term storage could be on the site where the item was recovered or at an off-property location. Long-term storage would be in an existing permanent ammunition storage facility in most cases.

On-property movement of a recovered CWM item has been described above. If an item must be moved to an off-property storage location, it would be moved as described in Section 3.1 for the preferred alternative. Restrictions on where items could be moved to are discussed in Section 1.6.

Any such storage would have to be approved and conducted in accordance with applicable RCRA and/or CERLA requirements as discussed in Sections 1.7 and 4.6.

1.10 Relationship of Proposed Action to Other Actions

This section describes the relationship of the proposed Army action to other ongoing and related programs that deal with non-stockpile and stockpile CWM.

1.10.1 Treatment and Destruction of Other Non-Stockpile Materiel

The NSCMP deals with other types of CWM in addition to the specific CWM considered in this environmental impact statement and described in Section 1.4. This other CWM materiel is the following:

- Binary chemical weapons
- Former chemical weapon production facilities
- Miscellaneous material that does not contain chemical agent but is associated with chemical warfare and comes under the provisions of the Chemical Weapons Convention

- Research, development, test, and evaluation materiel allowed under the Chemical Weapons Convention that would not be treated in transportable systems

Methods for the destruction and disposal of this materiel are being developed and implemented by NSCMP on separate schedules and program tracks. Appropriate and separate environmental reviews for the destruction methods and technologies for this materiel have been or will be completed, as required. The following reviews have been completed to date:

- Demolition of the Pilot Plant Complex at Aberdeen Proving Ground, MD (Department of the Army, 1998b, 1999a)
- Demolition phase I for the Chemical Warfare Agent Plant at Newport Army Depot, IN (Department of the Army, 1998a)
- M687 resource recycling reclamation for binary chemical warfare materiel at the Hawthorne Army Depot, NV (Department of the Army, 1997b)

The treatment and disposal of the CWM discussed above neither depends on nor is related to the decisions to be reached as a result of the analysis of the issues about the CWM treatment and disposal technologies considered in this programmatic environmental impact statement.

Some of the chemical samples currently being stored at a small number of locations may be treated at those locations using existing, permitted onsite facilities. This will be done in order to fulfill the requirements of the Chemical Weapons Convention in an expeditious manner. Environmental reviews of these operations will be conducted as required. This activity does not eliminate the need for the Army to develop and provide a capability to treat other non-stockpile CWM and would neither determine nor limit the alternatives being considered in this environmental impact statement.

1.10.2 Chemical Warfare Materiel Burial Site Remediation Programs

Buried CWM is subject to the requirements of RCRA, CERCLA, and similar laws. Under RCRA, buried CWM is classified as solid waste and also may be considered to be hazardous waste.

The responsibility to decide what remedy, if any, is needed at a CWM burial site rests with several DoD organizations, with USEPA, and/or with states. The NSCMP only assumes responsibility for the safe storage, treatment, and transport of CWM once it is recovered from the ground and presented for treatment. The responsibility for buried CWM sites is as follows:

- **Army, Navy, Air Force, Marine Corps, and Defense Logistics Agency.** Each organization is responsible for CWM burial sites on its installations.
- **U.S. Army Corps of Engineers.** CWM burial sites on formerly used defense sites that are no longer controlled by the DoD.

Other federal organizations would also be involved. For example, when CERCLA is the controlling law, the Agency for Toxic Substances and Disease Registry of the U.S. Department of Health and Human Services must complete an independent health assessment of human exposure to potential or actual releases of hazardous substances into the environment prior to completion of the remedial investigation. The U.S. Army Center for Health Promotion and Preventive Medicine serves as the DoD lead agent in relationship with the Agency for Toxic Substances and Disease Registry. The U.S. Army Center for Health Promotion and Preventive Medicine and the Agency for Toxic Substances and Disease Registry coordinate the Agency for Toxic Substances and Disease Registry's public health support to DoD for environmental cleanup activities.

Site-specific investigations and feasibility studies must be carried out under RCRA and CERCLA to determine whether and how to remediate any hazards associated with buried CWM sites. The DoD organization responsible for the site (see above) conducts these studies. Each responsible organization is also responsible for selecting the remedy needed, if any, at the site in consultation with the USEPA, state regulatory authorities, and the public. It is possible that at some sites, leaving suspect CWM in the ground may pose less risk to health, safety, and the environment than digging up the CWM and treating it, given the site-specific characteristics and current technology limitations.

The proposed Army action to complete development of transportable CWM treatment systems would neither preempt nor preclude the authority of local installation commanders and regulatory agencies from determining the appropriate remedy at a buried CWM site or the appropriateness of using the transportable treatment systems on a site-specific basis. The proposed Army action would also not prevent or eliminate public input to these decisions.

1.10.3 Chemical Stockpile Disposal Program

In 1985, the U.S. Congress enacted Public Law 99-145, which requires the U.S. Army to dispose of the U.S. stockpile of unitary chemical agents and munitions. After considering the environmental consequences of alternative disposal strategies (Department of the Army, 1988), the Army selected the alternative of onsite disposal by incineration as the baseline process for the disposal of a large quantity of specific chemical munitions and bulk quantities of chemical agent stockpiled at the following nine locations: Anniston Chemical Activity in Alabama; Pine Bluff Chemical Activity in Arkansas; Pueblo Chemical Depot in Colorado; Newport Chemical Depot in Indiana; Blue Grass Chemical Activity in Kentucky; Edgewood Chemical Activity in Maryland; Umatilla Chemical Depot in Oregon; Deseret Chemical Depot in Utah, and Johnston Island in the Pacific Ocean (Department of the Army, 1988). Currently, five of these stockpile locations (Anniston Chemical Activity, Pine Bluff Chemical Activity, Deseret Chemical Depot, Umatilla Chemical Depot, and Johnston Island) have established, or are in the process of establishing, disposal facilities to destroy stockpile munitions by separating the munitions into components (that is, chemical agents, components

with explosives or propellants, and components without explosives or propellants) and separately incinerating each of the components.

In 1992, the U.S. Congress enacted Public Law 102-484 that in part directed the Army to study potential alternatives to the baseline process for possible use at low volume stockpile sites. After evaluating the recommendations of the National Research Council and considering the comments provided by concerned citizens residing near each of the sites, the Army on January 17, 1997, authorized the continuation of steps toward implementing chemical neutralization of the bulk quantities of the stockpile of mustard agent at Edgewood Chemical Activity and bulk quantities of the stockpile of nerve agent VX at Newport Chemical Depot. In accordance with this authorization, the Army is currently preparing environmental impact evaluations for the construction and operation of the pilot plants at these two locations and is taking the steps necessary to obtain construction and operating permits for the pilot plants under RCRA and the Clean Air Act. Once the environmental impact evaluations have been completed and permits issued, the pilot plants would be used to demonstrate the neutralization of the chemical agent at each location. If the pilot plant demonstrations are successful, the pilot plants could then be used to treat the bulk quantities of chemical agent at each site. Additional environmental documentation and decisions would be required before this decision could be made.

In December 1996, the U.S. Congress enacted Public Law 104-208 that directed the Army to undertake a program to demonstrate no less than two alternatives to the baseline process for the stockpile of munitions and assembled chemical weapons. The program is to identify, test, and evaluate at least two alternative technologies and report the results to Congress. Until the identification and assessment of alternative technologies is completed, plans and funding have been suspended for the construction of stockpile disposal facilities using incinerators at the Pueblo Chemical Depot and Blue Grass Chemical Activity. After completion and submission of the Report to Congress, future determinations would need to be made regarding pilot plant demonstrations and whether any of the technologies would be used.

Unlike the stockpile of chemical munitions that are presently being or are to be treated at stockpile disposal facilities, non-stockpile CWM must first be assessed to determine the specific chemical fill. Non-stockpile CWM may also contain chemical agents (for example, nitrogen mustard) or industrial chemicals (for example, phosgene and cyanogen chloride), dating back to the era of World War I, that stockpile disposal facilities were not intended to treat. Only a limited quantity of the currently stored non-stockpile CWM (for example, a non-stockpile ton container of mustard agent) could be readily treated, from a purely technical standpoint, in stockpile facilities as currently developed or being developed. The Army's policy based on interpretation of Public Law 99-145 and its legislative history is that stockpile disposal facilities cannot be used for the treatment of non-stockpile CWM. Additionally, Public Law 99-145 requires that stockpile disposal facilities be "...cleaned, dismantled, and disposed of in accordance with applicable laws and regulations" when the stockpile facilities are no

longer needed for the disposal of the stockpile. The use of stockpile disposal facilities to treat a limited quantity of non-stockpile CWM, even if authorized, does not alleviate the need for the Army to develop and provide a capability for treating other non-stockpile CWM.

1.10.4 Commercial Treatment of Chemical Agent Identification Set Items

As part of the *National Defense Authorization Act for Fiscal Year 1998*, Congress directed that an assessment of policies for handling and disposal of CAIS items be completed with the intent of investigating alternatives that could result in reductions to the cost of demilitarizing these items. As an initial phase of this assessment, the NSCMP has investigated the potential destruction of CAIS using commercial hazardous waste treatment and disposal facilities. Based on the initial assessment, the NSCMP has identified that (1) there are no known technical limitations that would prevent the effective destruction of unpackaged CAIS materiel containing mustard agent and lewisite in commercial treatment and disposal facilities; (2) federal law would need to be clarified in regard to the definition of "lethal chemical agent" to allow the commercial treatment and disposal of CAIS items containing mustard agent and lewisite; and (3) when only a small number of CAIS items are found at a site, the use of commercial treatment and disposal facilities could result in considerable cost savings to the costs of deploying and treating a limited number of CAIS items with the RRS described in Section 2 and Appendix C. A final report on alternatives that could reduce costs of demilitarizing CAIS items is to be written in coordination with the National Research Council and is planned for publication in 1999.

Using commercial treatment facilities to treat a limited number of CAIS items does not eliminate the need for the Army to develop and provide a capability for treating large quantities of CAIS that could be recovered at a site. Also, studies to date confirm that an RRS-type capability is required to open metal "pig" containers for CAIS material recovered in that configuration.

1.11 Scoping Process

The NSCMP solicited public input to this environmental impact statement from 16 October 1996 through 28 February 1997. The NSCMP used several means to accomplish this public scoping process:

- Held five regional public scoping meetings (Salt Lake City, Utah; Rockville, Indiana; San Antonio, Texas; Huntsville, Alabama; and Tampa, Florida) at which the public could view exhibits and information stations; obtain informational materials; and talk with representatives of the NSCMP, local military installations, U.S. Army Corps of Engineers, and U.S. Department of Health and Human Services.
- Placed advertisements that gave specific information about scoping meetings, information repositories, toll-free telephone numbers, and an Internet address in 51 newspapers in the vicinity of known or suspected non-stockpile CWM locations.

- Placed information about the NSCMP and the environmental impact statement in 50 information repositories and on the Internet.
- Established a toll-free telephone number for use by interested individuals and organizations to request information or record comments.

A total of 35 individuals, organizations, and government agencies submitted comments during the scoping period. Issues most often raised by commentors were the following:

- Public health and safety
- Environmental justice
- Relationship of the NSCMP to local installation restoration programs
- Compliance with regulatory requirements
- Transportation impacts

The NSCMP has prepared a *Scope of Statement* for this impact statement that documents the efforts of the NSCMP to involve interested individuals and organizations in the public scoping process. This document includes the scoping comments and suggestions received by the NSCMP, how the comments and suggestions were considered by the NSCMP, and the NSCMP's determinations on the scope of the environmental impact statement as a result of the scoping process.

Several other issues were raised that are not addressed in this environmental impact statement. These issues are briefly discussed below.

Site- or Location-Specific Comments. Some comments were about site-specific or location-specific issues. These comments included those that (1) suggested the environmental impact statement identify and evaluate the current hazardous waste facilities and RCRA compliance status of facilities at each site or location with non-stockpile CWM, and (2) requested the evaluation of site-specific impacts, such as the extent to which wetlands or historic and cultural sites would be affected. These issues have not been included because this environmental impact statement does not address deployment of the transportable treatment systems at specific sites or locations. It only addresses the generic issue of whether development of these systems should be completed and the systems made available for deployment in the field. If this decision is affirmative and these systems become available for deployment at a specific site, they would be deployed only after an analysis of the specific environmental impacts that could occur at that site. These subsequent site-specific analyses would consider the impacts of locating transportable chemical treatment units at a specific site, including such site-specific impacts as to what areas containing significant ecological resources and archaeological, historic, or culturally significant sites would be affected. These site-specific analyses will include public input and the consideration of public comments.

Remediation of Buried CWM Sites. Some comments were requests for detailed information on what is buried in CWM burial sites, and some of the comments suggested that the impact statement evaluate the impacts of remedial action at CWM burial sites. The NSCMP has prepared a draft document entitled the *Survey and Analysis Report* (Department of the Army, 1996a) that identifies the CWM burial sites and the general types of CWM that may be buried. Currently, there is a high degree of uncertainty regarding the quantities and specific types of CWM that may have been buried and the number of sites at which CWM has actually been buried. Additional information on the types and quantities of CWM will not be available until preliminary assessments and investigations are carried out at specific burial sites.

The impacts of remediating CWM burial sites will be determined in site-specific investigations prepared under the provisions of CERCLA or RCRA. These investigations will be carried out before selecting and implementing specific remediation measures at CWM burial sites. This environmental impact statement only addresses the generic issue of whether development of transportable treatment systems should be completed and the systems made available for deployment in the field. It does not address how individual burial sites should be remediated.

Funding of Installation Restoration Programs and Cost of Adverse Impacts. A few comments suggested that military installation restoration programs should be unconditionally funded and that the environmental impact statement should include an economic assessment of adverse effects to public health, welfare, the environment, and ecosystems. The purpose of any environmental impact statement is to discuss the environmental and socioeconomic consequences of a contemplated action and the reasonable alternatives to the proposed action. The amount of funding authorized and appropriated by Congress, and the limitations imposed by Congress on the use of authorized and appropriate funds, are not subject to the requirements of the National Environmental Policy Act. This act does not require that a monetary cost-benefit analysis be carried out when preparing an environmental assessment or an environmental impact statement.

Evaluation of Other Technologies. Several comments suggested that other technologies should be evaluated in the environmental impact statement, and several commentors stated opposition to the use of incineration. This impact statement is not intended to be an evaluation or a selection of alternative treatment technologies. Although there are other technologies that might be able to be used for the treatment of non-stockpile CWM if further developed, only the proposed chemical treatment systems have been sufficiently developed as part of an integrated transportable treatment system for non-stockpile CWM. The decision to be made at this time is whether to complete development of these systems and make them available for deployment in the field. Instead of a detailed evaluation, this impact statement identifies and describes other technologies that could be developed in the future, and public input is sought on which, if any, of these other technologies the NSCMP should consider. A decision by the Army to complete development of the proposed transportable chemical treatment systems and to make them

available for deployment does not preclude the Army from developing other technologies in the future that may provide significant advantages in cost, safety, and protection of human health and the environment.

Section 2

Transportable Treatment Systems and Support Facilities and Equipment

The Army is developing four types of integrated transportable treatment systems for non-stockpile chemical materiel (Table 2-1). These systems are summarized below and described in more detail in Appendix C.

Each transportable treatment system would use a chemical process as the treatment method for chemical warfare agents and sometimes for the industrial chemical phosgene. Chemical agent would be mixed with other chemicals, called treatment reagents, which convert the chemical agent into waste chemical compounds, called neutralent waste. The neutralent waste could be handled and disposed of like similar hazardous chemical wastes from regular industrial processes. As a result, the treatment wastes would be sent to commercial TSDFs that specialize in industrial hazardous waste treatment. These facilities would carry out additional treatment of the wastes and dispose of the residue in accordance with RCRA and other federal and state regulations.

Industrial chemicals would be removed from the munition or original container and repackaged in new containers that meet regulatory requirements for shipping. The containers would be transported to a commercial TSDF for treatment and final disposal.

The descriptions of the treatment systems and treatment processes below are based on the current state of development of these systems. Development is continuing on treatment processes. The chemistry of these processes will not be known completely until testing of the treatment systems is completed.

The treatment systems described below are still being tested. The procedure that the Army will follow to complete this process is as follows. Once a prototype system is assembled, testing begins. A factory acceptance test is conducted to ensure the hardware meets Army specifications. A system test using CWM simulants is then conducted following a written procedure to ensure operators can use the system and operating procedures safely and effectively. Finally, the system is tested using real non-stockpile CWM items. After all tests, the data are analyzed and any needed modifications are made to the equipment, hardware, treatment chemistries, or operating procedures to ensure system safety and effectiveness. The NSCMP also uses a Programmatic Lessons Learned system so that problems and solutions for one type of treatment system can be reviewed to determine how similar solutions can be implemented on other types of treatment systems.

Table 2-1. Transportable Treatment Systems

System	Type of Non-Stockpile Chemical Materiel Treated	Status
Rapid Response System (RRS)	Chemical agent identification sets	Full-scale prototype designed and assembled
Munitions Management Device–Version One (MMD-1)	Non-stockpile chemical munitions without explosive components Small containers of chemical agent Chemical samples	Full-scale prototype designed and assembled
Munitions Management Device–Version Two (MMD-2)	Non-stockpile chemical munitions with explosive components that are safe to handle and transport Bulk items up to large bombs and one-ton containers using bulk item accessing equipment	Full-scale prototype in design; explosive containment chamber tested
Explosive Destruction System (EDS)	Chemical munitions with explosive components that are not safe to handle or transport Chemical munitions, with or without explosive components	EDS Phase I prototype in testing. EDS Phase II model in design.

An overview of each of the treatment systems is given below. Described are the major components and facilities required for operating the systems at a site, the safety monitoring systems that would be operated, the chemical treatment process that would be used, and the staffing and utilities required for site operation.

A brief explanation of storage facilities, storage containers, and monitoring systems is also provided in this section. Appendix C provides a more detailed description of each treatment system and supporting equipment.

2.1 Rapid Response System

The RRS is a transportable treatment system for CAIS items. It is capable of safely treating chemical agents and repackaging industrial chemicals contained within CAIS items. See Appendix C.2 for more information on the RRS.

2.1.1 Components

The RRS consists of an operations trailer, utility trailer, and other support systems as needed at a specific site. Figure 2-1 is a conceptual site plan for an RRS operation showing the facilities that could be needed. Figure 2-2 shows the RRS operations trailer and its support trailer. Table 2-2 provides a description of each of the major components.

2.1.2 Treatment Operations

CAIS would be brought into the operations trailer and placed into the glovebox system for processing. The flow of process operations within the RRS operations trailer is shown in Figure 2-3. The processing compartments within the glovebox system are shown on Figure 2-4.

Overpack containers of CAIS items would be brought to the loading station at the operations trailer and placed on a cart. The container and any required tools and equipment would then be placed into the airlock station. Negative pressure would be restored once the materials are in the airlock. The CAIS container would then be moved to the unpack station.

CAIS ampoules and bottles would be removed in the unpack station and their contents identified using a Raman spectrophotometer. Ampoules and bottles of chemical agent would be separated by content and stored in the unpack station until enough are accumulated for treatment in the neutralization station. Dunnage and packing material from the CAIS would be stored in a waste drum. If a spill of agent occurs in the unpack station, the spill and materials would be decontaminated and the waste placed into the waste drum under the unpack station.

Ampoules and bottles containing industrial chemicals would be repackaged in the unpack station into intermediate containers. These containers would be monitored to ensure no ampoules or bottles are leaking. These containers would then be removed from the glovebox through the airlock station. Outside of the operations trailer the intermediate containers would be placed into overpacks approved by USDOT for shipment to the disposal location.

Ampoules and bottles containing chemical agent would be processed in the neutralization station. Only three ampoules or one bottle would be processed at a time. The ampoules or bottles would be placed in a small reactor vessel (not more than one gallon) and the vessel sealed. The items would then be crushed and the released contents treated with the appropriate treatment chemicals. The resulting waste contents in the reactor vessel would be placed in the waste drum under the neutralization station.

When operations are finished at a site, the glovebox system will be cleaned, decontaminated, and closed before the operations trailer is moved from the site. Wastes from cleaning and decontaminating would be placed in containers.

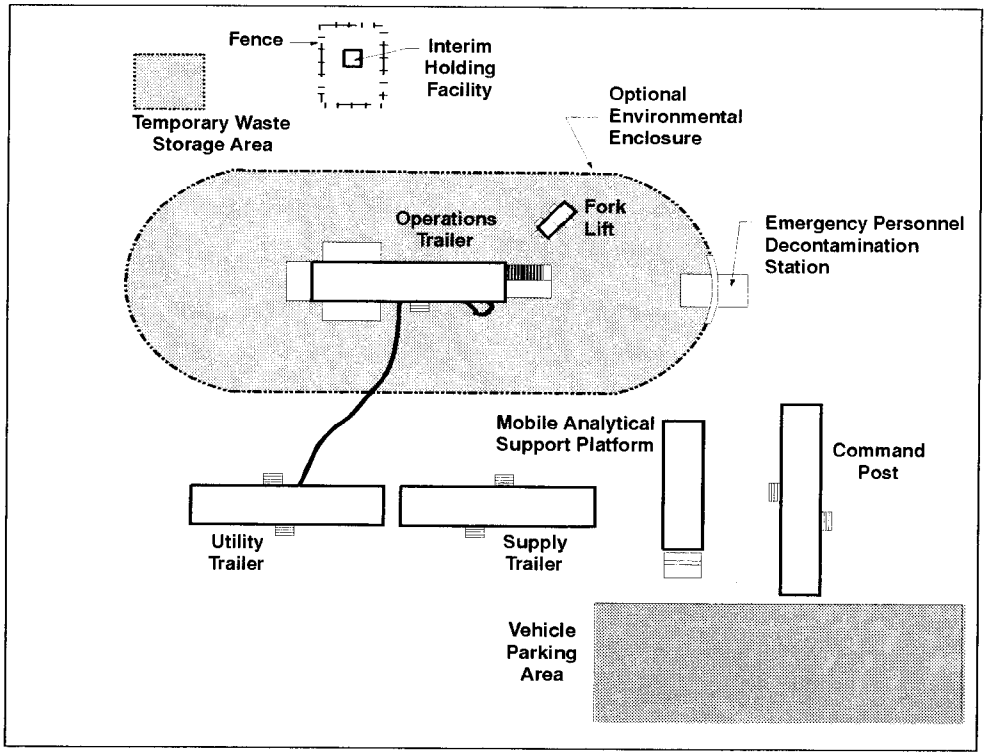


Figure 2-1. Conceptual Site Layout of the Rapid Response System

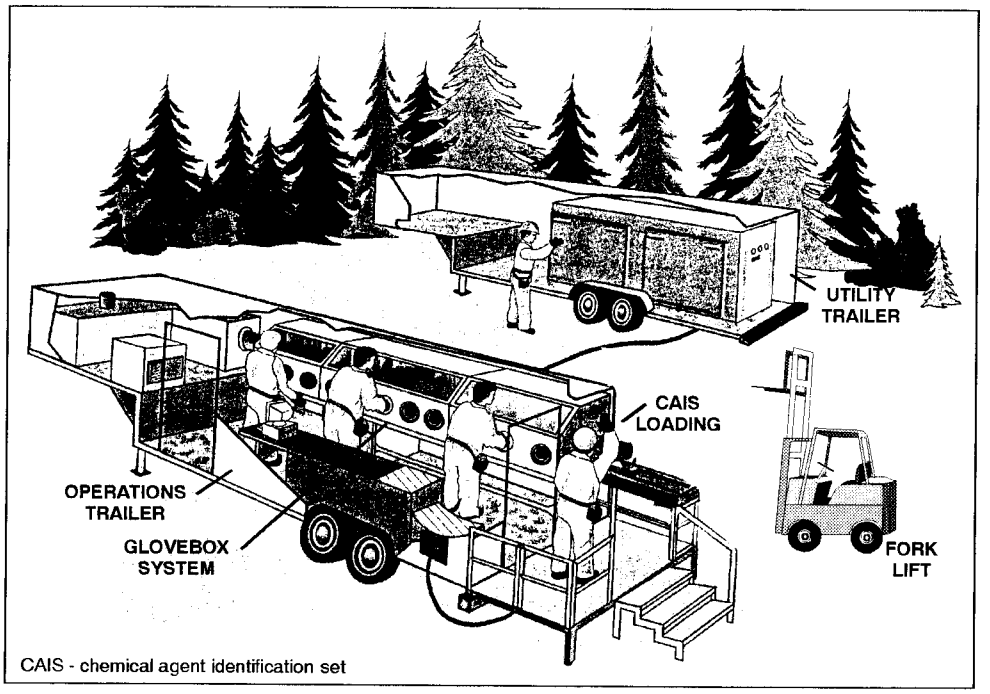


Figure 2-2. Conceptual Drawing of the Rapid Response System

Table 2-2. Components of a Treatment Site for a Rapid Response System

Component	Description
Operations Trailer	The operations trailer contains the equipment, systems, and instrumentation needed to treat CAIS items. The trailer has a loading system at one end. From the loading system, CAIS would enter a sealed glovebox system inside the trailer within which opening and processing of the CAIS items would take place (Figure 2-2). Process wastes would be collected in the waste containerization system.
Utility Trailer	The utility trailer contains two diesel-powered generators. One generator would provide electrical power for the site if external power were not available. The other generator would be a backup and emergency generator. The backup generator could provide power to certain systems in the operations trailer if external or primary generator power is lost. The backup generator would be operational within 30 seconds of the loss of primary power.
Mobile Analytical Support Platform	The mobile analytical support platform could screen chemical agent concentration in samples before they are sent to a RCRA-certified laboratory, analyze depot area air monitoring system sample tubes, and prepare and store calibration samples for monitoring equipment.
Environmental Enclosure	The RRS would operate in the open. However, the system could be operated in an appropriate existing building or an environmental enclosure if an additional level of vapor containment or protection from the environment would be needed. An environmental enclosure (if used) would consist of flexible walls over a rigid framework with a portable ground cover liner.
Additional Support Facilities	Additional support facilities could be needed when the available infrastructure is unable to meet certain requirements. The equipment would include a command post, supply trailer, interim holding facility, temporary waste storage area, and parking area.

CAIS – Chemical agent identification sets
RCRA – Resource Conservation and Recovery Act
RRS – Rapid Response System

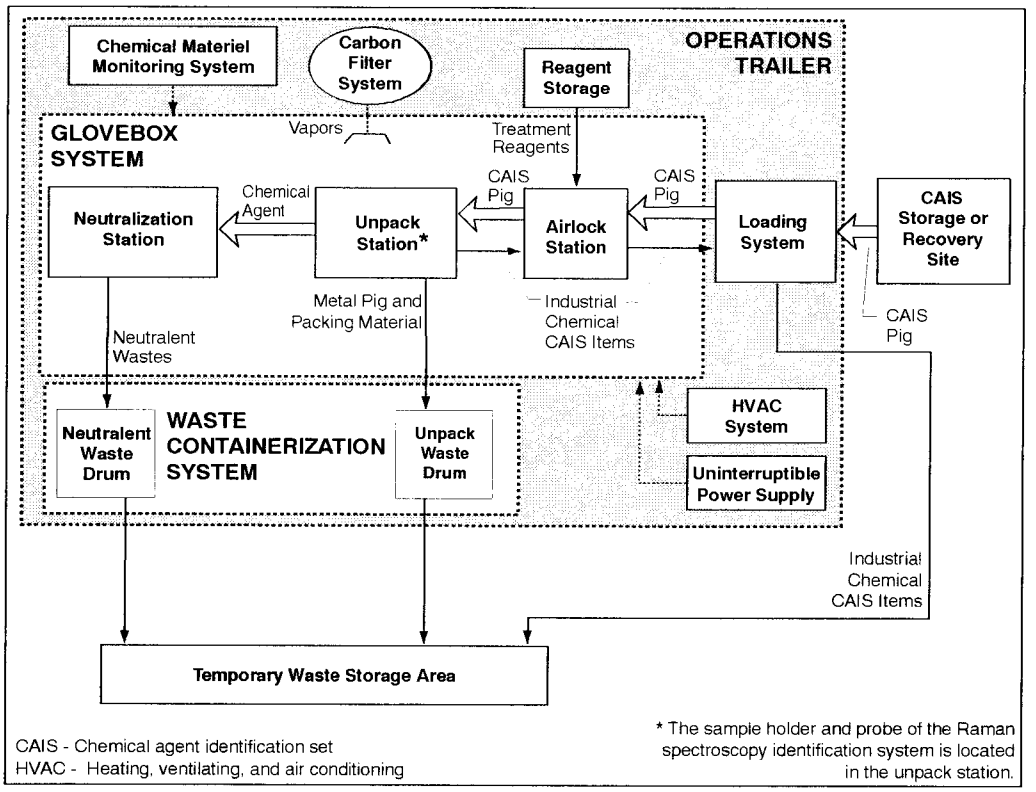


Figure 2-3. Process Flow Diagram for the Rapid Response System

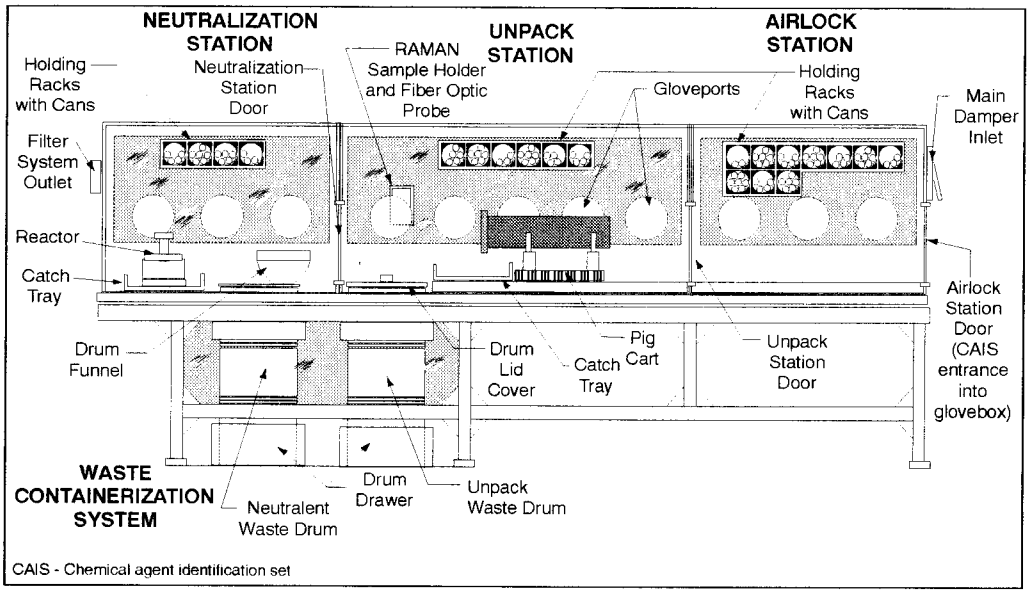


Figure 2-4. Glovebox and Waste Containerization Systems in the Operations Trailer of the Rapid Response System (Side View)

2.1.3 Process Waste Disposal

Process wastes from treating CAIS items in the operations trailer would be contained in 30-gallon (114-liter) drums under the unpack station and the neutralization station (Figure 2-4). Wastes in the drums would consist of liquid neutralents from the neutralization process, metal parts, glass, and packing materials. Sealed waste drums would be removed periodically and placed in the temporary storage area until shipped to the commercial industrial waste treatment and disposal facility. Additional site wastes are discussed in Section 3.1.10.

2.1.4 Site Operating Requirements

The RRS could be set up and operated on about about 1 acre (0.4 hectares) of land. Operation would require about 17 people. Existing potable water and wastewater disposal systems would be used if available. Transportable systems would be used if existing systems were not available. Using existing electricity sources is preferred. If no existing electricity source were available, the primary generator in the utility trailer would be used to generate site electricity.

2.2 Munitions Management Device–Version One

The Munitions Management Device–Version One (MMD-1) is a transportable chemical treatment system for chemical munitions without explosive components and for small containers of chemicals with diameters of not more than 8 inches (20 centimeters). Munitions that could be treated include mortar and artillery projectiles, bombs up to about 115 pounds (52 kilograms), and bomblets. The MMD-1 could also treat a variety of chemical agent storage and shipping containers. Industrial chemicals would be removed from munitions or other original containers and repackaged into new containers.

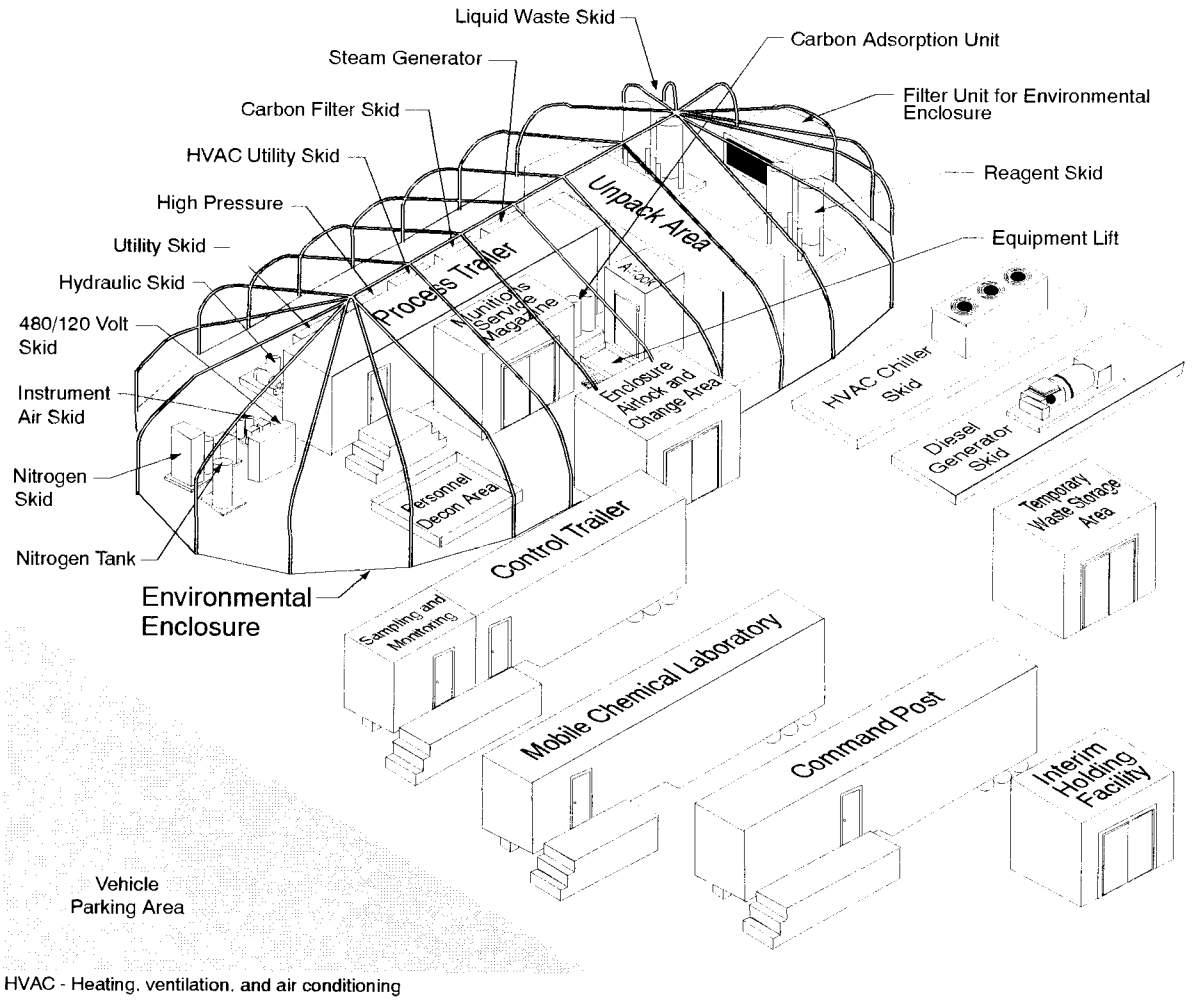
Figure 2-5 is a conceptual site plan for an MMD-1 operation showing the facilities that could be needed. See Appendix C.3 for more information on the MMD-1.

2.2.1 Components

The MMD-1 consists of an unpack area, a process trailer, a control trailer, and several process and utility systems. The components that have the potential for internal chemical agent contamination would be located within an appropriate building (if available at the site) or an environmental enclosure. Accessing and treating CWM would take place in the process trailer. The treatment process would be controlled and monitored from the control trailer. Table 2-3 provides a brief description of the MMD-1 components.

2.2.2 Treatment Operations

Unpacking and processing of CWM items would take place in the unpack area and the process trailer. Figure 2-6 shows the process flow.



HVAC - Heating, ventilation, and air conditioning

Figure 2-5. Conceptual Site Layout of the Munitions Management Device - Version One

Table 2-3. Components of a Treatment Site for a Munition Management Device–Version One

Component	Description
Unpack Area	The unpack area is a single-story modular building with a sump under the floor. Personnel in protective clothing would unpack a CWM item from any overpack container, examine it, ensure that the item could be processed in the MMD-1, seal any leaks, and install the item in a holding fixture. The layout of the unpack area is shown in Figure 2-7. The unpack area could also be used to clean and cutup (if needed) empty decontaminated munitions that have been processed in the process trailer. Waste material from this activity would be placed in containers for recycling or for additional treatment, as required, and disposal.
Process Trailer	In the process trailer, CWM items would be processed by remote control from the control trailer. Figure 2-8 shows the layout of the process trailer. The forward area of the trailer contains instrumentation and electrical panels, connectors, and equipment. The rear area contains all of the munitions and container accessing and treatment systems.
Control Trailer	The control trailer contains the systems and equipment for remotely controlling the processes and systems in the process trailer. Figure 2-9 shows the layout of the control trailer.
Mobile Chemical Laboratory	Laboratory analyses would be conducted in a mobile chemical laboratory trailer. The laboratory satisfies Army requirements for a research, development, test, and evaluation facility that handles dilute chemical agent solutions.
Environmental Enclosure	An environmental enclosure would be used when there is no suitable existing building to house the MMD-1 components that have the potential for internal chemical agent contamination. An environmental enclosure would consist of flexible walls over a rigid framework with a portable ground cover liner.
Support Systems and Utilities	Various support units on skids would be required to operate the MMD-1. These skids would provide carbon filtration, carbon absorption, reagent storage, waste and surge storage, hydraulic power, instrument air, nitrogen, electric power, emergency power, steam, high-pressure wash, and heating, ventilation, and air conditioning.
Additional Support Facilities	Additional support facilities could be needed when the available infrastructure is unable to meet certain requirements. The facilities would include a command post, interim holding facility for CWM items, temporary waste storage area, laundry trailer for cleaning personal protective equipment, and parking area.

CWM – Chemical warfare materiel
MMD-1 – Munitions Management Device–Version One

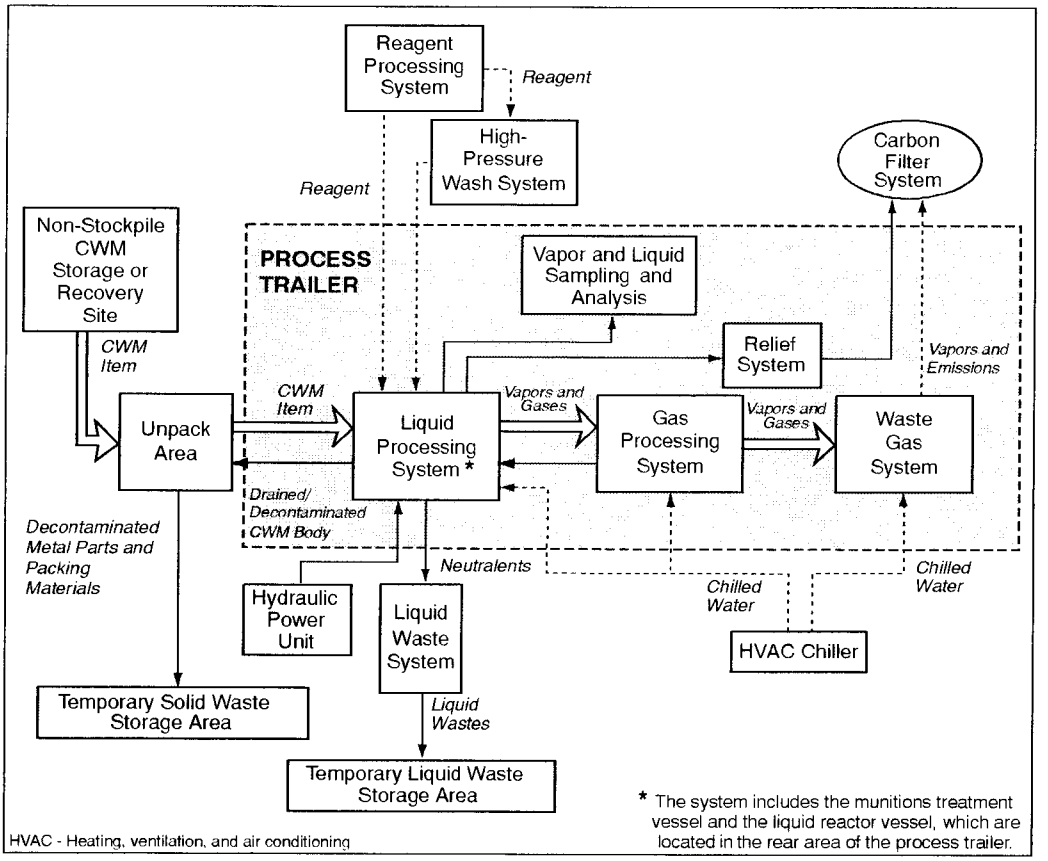


Figure 2-6. Process Flow Diagram for the Munitions Management Device - Version One

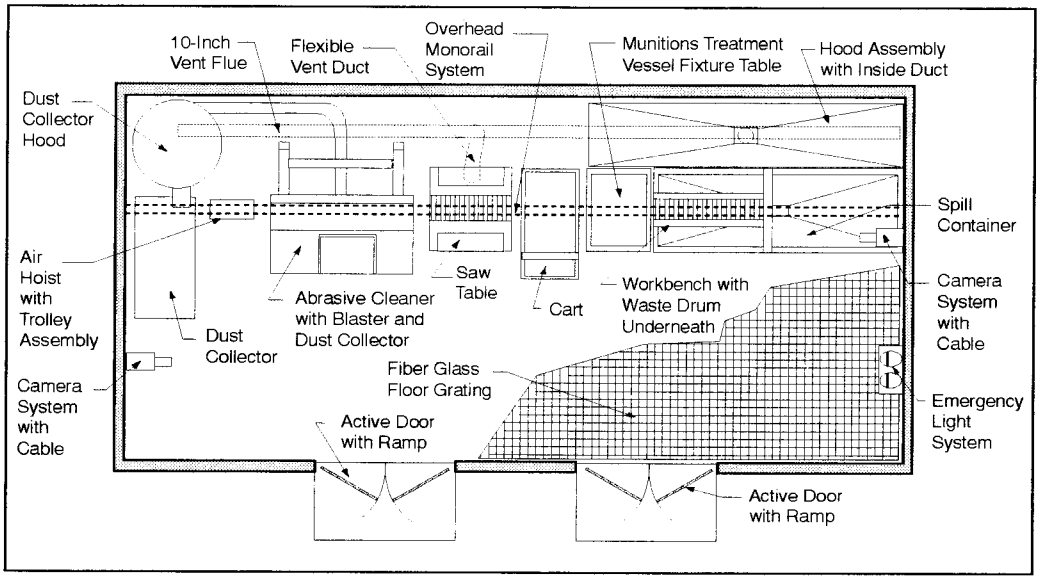


Figure 2-7. Plan View of the Unpack Area of the Munitions Management Device - Version One

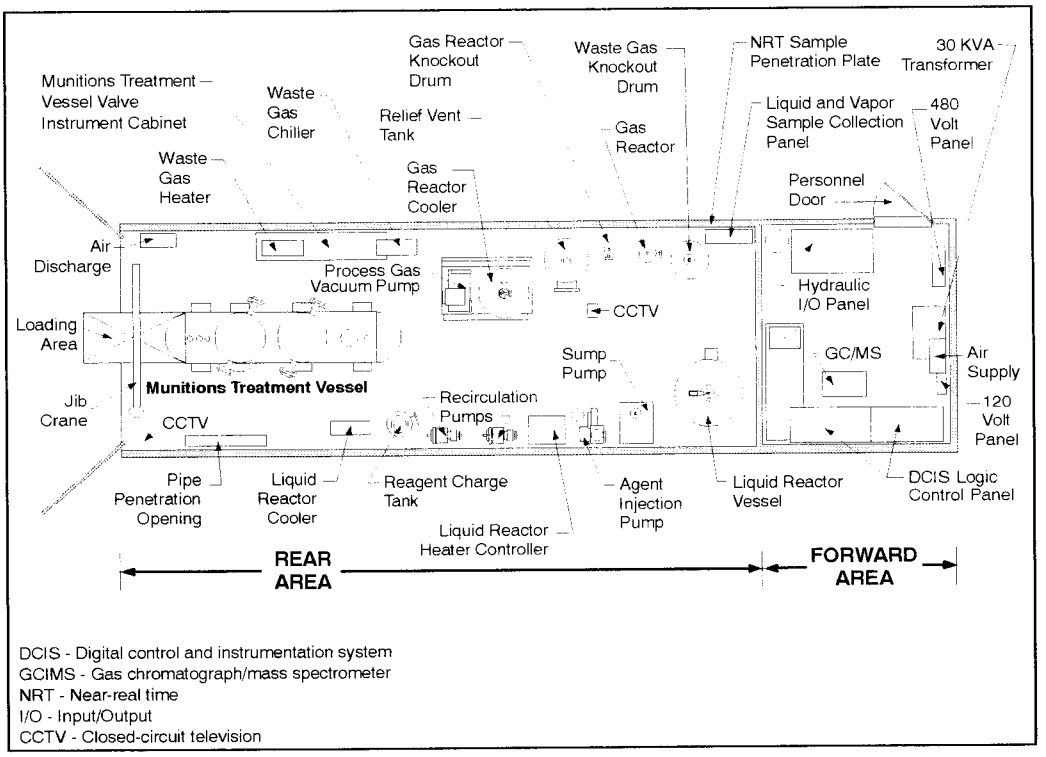


Figure 2-8. Plan View of the Process Trailer of the Munitions Management Device - Version One

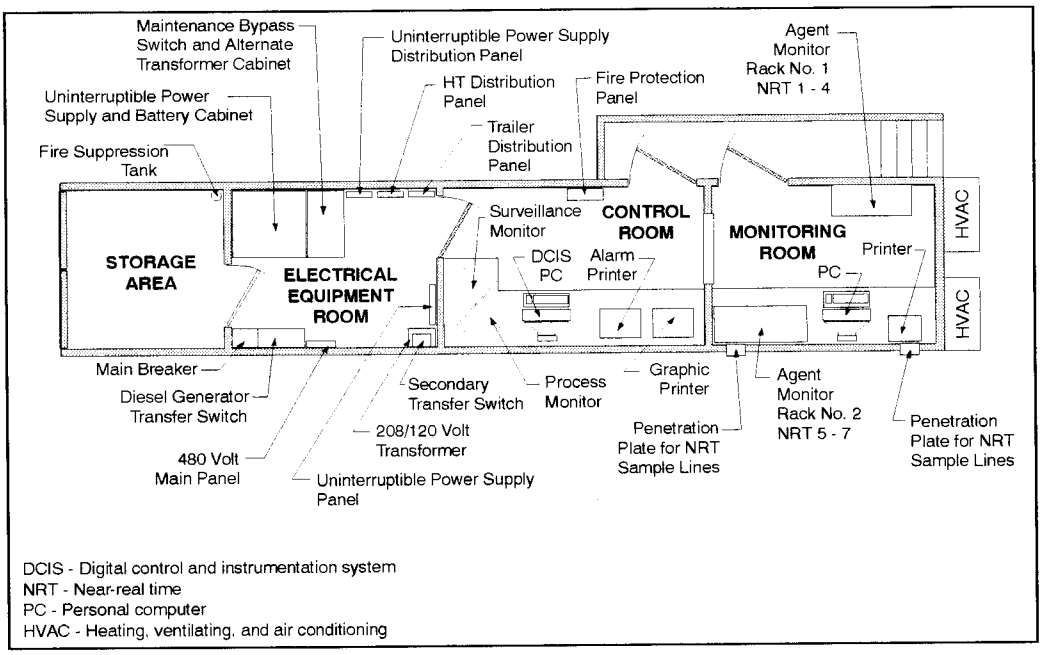


Figure 2-9. Plan View of the Control Trailer of the Munitions Management Device - Version One

CWM items would be brought to the unpack area to begin processing. Each item would be monitored for leaks in the unpack area. If not leaking it would be removed from its overpack, installed on a holding fixture, and placed onto a cart for transport into the process trailer.

In the process trailer, the CWM item would be manually loaded into the munitions treatment vessel. The vessel would be sealed and pressurized with nitrogen. Operations after this point would be remotely controlled from the control trailer.

The CWM item would be positioned in the munitions treatment vessel and a hole would be drilled in the item to release any vapor. The vapor would be analyzed to confirm that the type of chemical fill is the same as was determined earlier by another method. The fill would then be drained from the item and mixed with the appropriate treatment reagent in the munitions treatment vessel. If the volume of chemical fill were too great for the vessel, the fill would be transferred through pipes to a liquid reactor vessel to be mixed with the treatment reagent. Any gases released would be processed in the gas processing system.

When the treatment reaction is complete, the neutralent waste would be sampled to confirm the treatment was effective. If not effective, additional reagent would be added. If effective, the neutralent waste would be transferred to waste storage tanks, where it would be held until transferred to shipping containers meeting USDOT standards and characterized in accordance with RCRA requirements.

The drained chemical munition or container would be decontaminated in the munitions treatment vessel by flushing with the appropriate treatment reagent and rinsing with water. Decontamination is determined to be complete by monitoring the air in the vessel and container. The decontaminated item and holding fixture would be removed from the vessel and taken to the unpack area. In the unpack area, the item could receive addition handling and management (such as sectioning it to reduce its size) to prepare it for recycling or disposal. All solid waste would be placed in containers and held until shipped for recycling or disposal.

2.2.3 Process Waste Disposal

All process wastes held in the liquid waste system would be transferred to appropriate sealed containers and characterized as required by RCRA. Wastes that could possibly be contaminated with chemical agent would be sampled and analyzed for chemical agent concentration. Additional wastes generated at the site are described in Section 3.1.10.

2.2.4 Site Operating Requirements

The MMD-1 could be set up and operated on about about 1.5 acres (0.6 hectares) of land. About 40 people would be required to assemble and set up the system. About 20 people would be needed per shift to operate the system. There could be two operating shifts each day.

Existing potable water and wastewater disposal systems would be used if available. Portable systems would be used if existing systems were not available. Existing electric

utility systems would be used to supply power to the site. Diesel-powered generators would be used if utility power is not available.

2.3 Munitions Management Device–Version Two

The Munitions Management Device–Version Two (MMD-2) is a transportable chemical treatment system for CWM munitions with and without explosive components, shipping and storage containers, and chemical samples. The MMD-2 is designed to treat the chemical agents mustard, sarin, and VX and to repackage the industrial chemicals cyanogen chloride and chlorine. The MMD-2 could either treat or repackage phosgene. The MMD-2 could process munitions and containers with a maximum diameter of about 8 inches (20 centimeters). If a bulk item accessing equipment trailer is also at the site, the MMD-2 can process large bulk items, such as ton containers, large bombs, and containers with diameters greater than 8 inches (20 centimeters).

Figure 2-10 is a conceptual site plan for an MMD-2 operation showing the facilities that could be needed. See Appendix C.4 for more information on the MMD-2.

2.3.1 Site Components

The MMD-2 would comprise of several trailer units and support utility systems transportable by road, railroad, or barge. Table 2-4 provides a brief description of the components.

2.3.2 Treatment Operations

Processing of munitions and containers would take place in several trailer systems. Figure 2-11 shows the process flow.

There are two ways items could be processed. Munitions with explosive components would be sent to the explosive containment chamber. Items without explosive components that fit could also be processed in this chamber. Large items without explosive components would be sent to the bulk item accessing equipment trailer.

2.3.2.1 Munitions Less than 20 Centimeters in Diameter

A CWM item would be brought to the unpack area trailer. There it would be removed from its overpack and x-rayed as appropriate to verify the internal configuration of munitions and to help determine the location to access the chemical fill. Items would then be transferred from the unpack area trailer into the explosive containment chamber trailer through an airlock corridor. In the explosive containment chamber, the munition would be placed into an auxiliary process vessel where it would be breached and the vapor sampled to confirm the type of chemical fill. Then the contents would be drained. Only one munition would be accessed at a time.

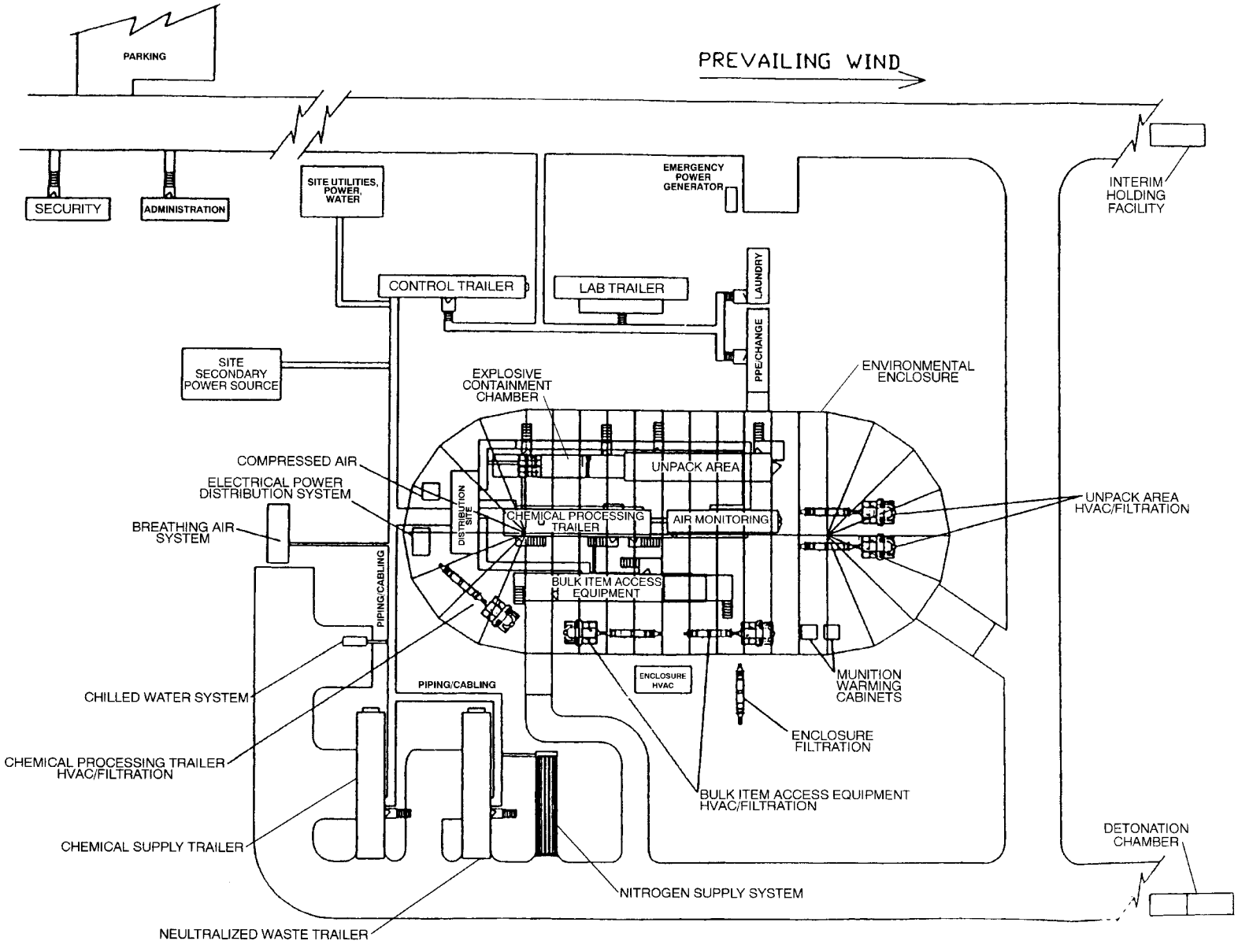


Figure 2-10. Conceptual Site Plan for the Munitions Management Device - Version Two

Table 2-4. Components of a Treatment Site for a Munition Management Device–Version Two

Component	Description
Unpack Area Trailer	The unpack area trailer would handle munitions and containers before and after processing. Munitions and containers would be removed from overpacks and prepared for handling and processing. Munitions casings and containers drained in the explosive containment chamber trailer would be returned to the unpack area trailer to be decontaminated and prepared for additional handling and processing as required. Figure 2-12 shows the layout of the unpack area trailer.
Munitions Warming Cabinet	The munitions warming cabinet would be used, if required, to warm items containing mustard agent before they are moved to the unpack area trailer. Mustard agent is solid at temperatures of 15°C or less and must be warmed to the liquid form before processing so that the mustard fill can be drained for treatment.
Explosives Containment Chamber Trailer	The explosive containment chamber trailer would receive the unpacked munitions or containers. The chamber would access and drain the fill from munitions and from containers. The chamber is designed to withstand detonations of 13 pounds of TNT equivalent, which is more than the amount of explosive in any item likely to be processed. All vapors and fragments would be contained if a detonation occurs. Figure 2-13 shows the layout of the explosive containment chamber.
Chemical Processing System Trailer	The chemical processing system trailer would receive the chemical fills drained from munitions and containers in the explosive containment chamber trailer. Chemical fills would be treated in the chemical processing system. Industrial chemicals that are not to be treated would be transferred directly to appropriate containers. Figure 2-14 shows the layout of chemical processing system trailer.
Control Trailer	The control trailer (Figure 2-15) contains the systems and equipment for personnel to use to control all materiel accessing and treatment operations carried out in other trailers. This trailer would be located outside of the environmental enclosure (Figure 2-10).
Bulk Item Accessing Equipment Trailer	The bulk item accessing equipment trailer is used to handle and prepare large bulk items without explosive components. The trailer contains equipment to access and drain the fill from items received. Chemical agents drained from items would be transferred to the chemical processing trailer. Industrial chemicals drained from items would be transferred to containers for disposal. Drained items could also be decontaminated and prepared for disposal in the trailer. Figure 2-16 shows the trailer layout.

Table 2-4. (Concluded)

Component	Description
Detonation Chamber Trailer	The detonation chamber trailer would be used to detonate the explosive components of a munition after it is drained and decontaminated. All fragments from the detonation would be contained in the chamber. After the detonation, chamber air would be vented through a filter system. Figure 2-17 shows the detonation chamber system on its trailer.
Chemical Supply System Trailer	Treatment reagents and process water would be stored in the chemical supply trailer to be used to treat chemical fill drained from munitions and containers and to decontaminate drained items and equipment. Reagent and process water would be passed from the chemical supply trailer through piping to the other trailers where it is used.
Neutralized Waste System Trailer	Liquid waste generated during treatment of chemical fills and from decontamination activities in the other processing trailers would be stored temporarily in the neutralized waste system trailer. The trailer would have several stainless steel tanks equipped with agitators and sample collection ports. One large tank would receive and hold waste from decontamination and rinsing operations.
Mobile Chemical Laboratory Trailer	Laboratory analyses would be conducted in a mobile chemical laboratory trailer. The laboratory satisfies Army requirements for a research, development, test, and evaluation facility that handles dilute chemical agent solutions.
Environmental Enclosure	An environmental enclosure would always be used with an MMD-2 system (Figure 2-10). The enclosure would house those MMD-2 components that have the potential for internal chemical agent contamination. An environmental enclosure would consist of flexible walls over a rigid framework with a portable ground cover liner.
Support Systems and Utilities	Various support units would be required to operate the MMD-2. These systems include an emergency power generator, instrument air compressor, chilled water system, breathing air system, nitrogen supply trailer, personal protective equipment change-out trailer, and distribution skid.
Additional Support Facilities	Additional support facilities would be needed when the available infrastructure is unable to meet certain requirements. The facilities would include an administrative trailer, interim holding facility, temporary waste storage area, parking area, and personal protective equipment laundering facility.

MMD-2 – Munitions Management Device–Version Two
TNT – Trinitrotoluene

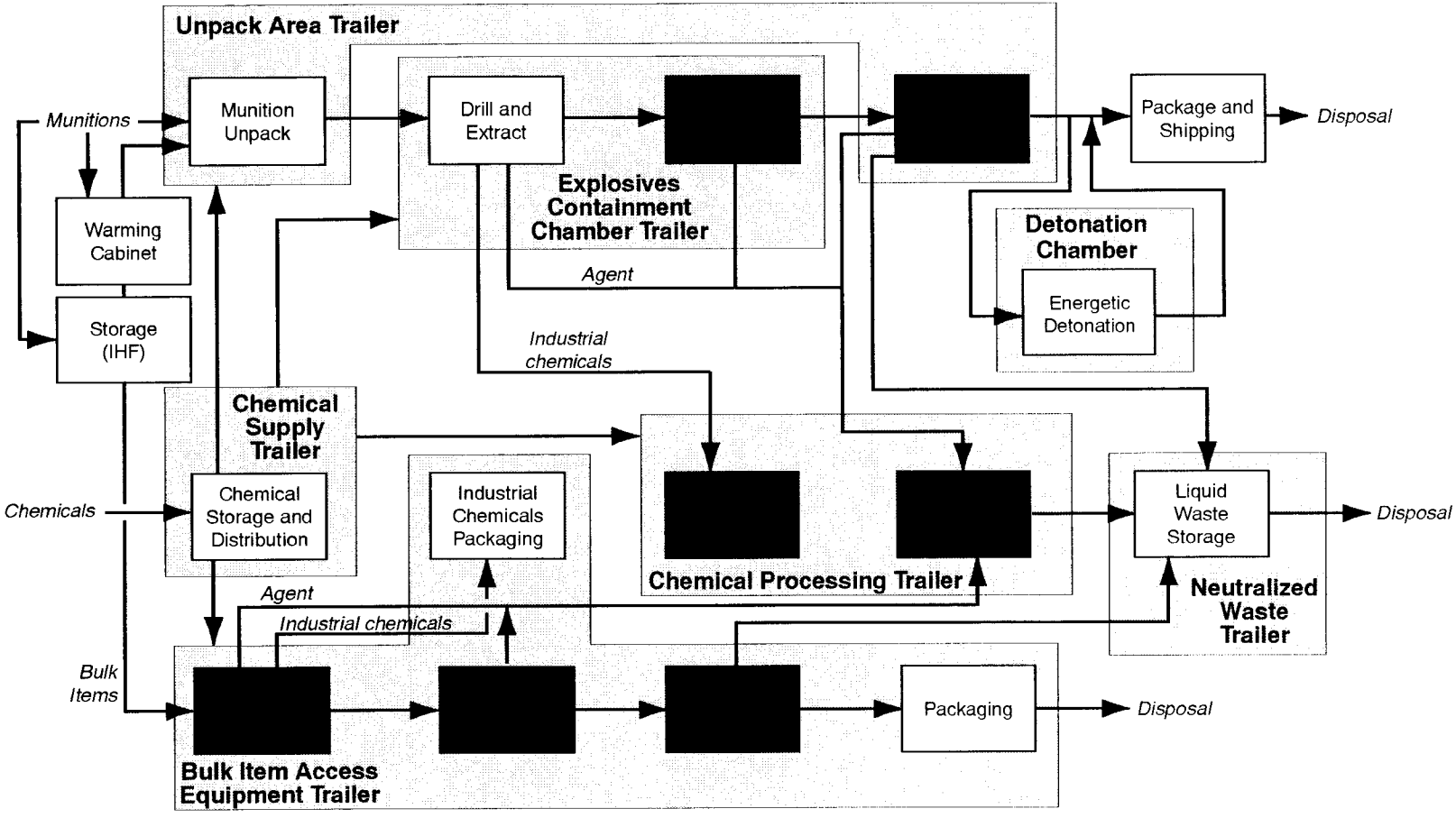


Figure 2-11. Process Flow Diagram for the Munitions Management Device - Version Two

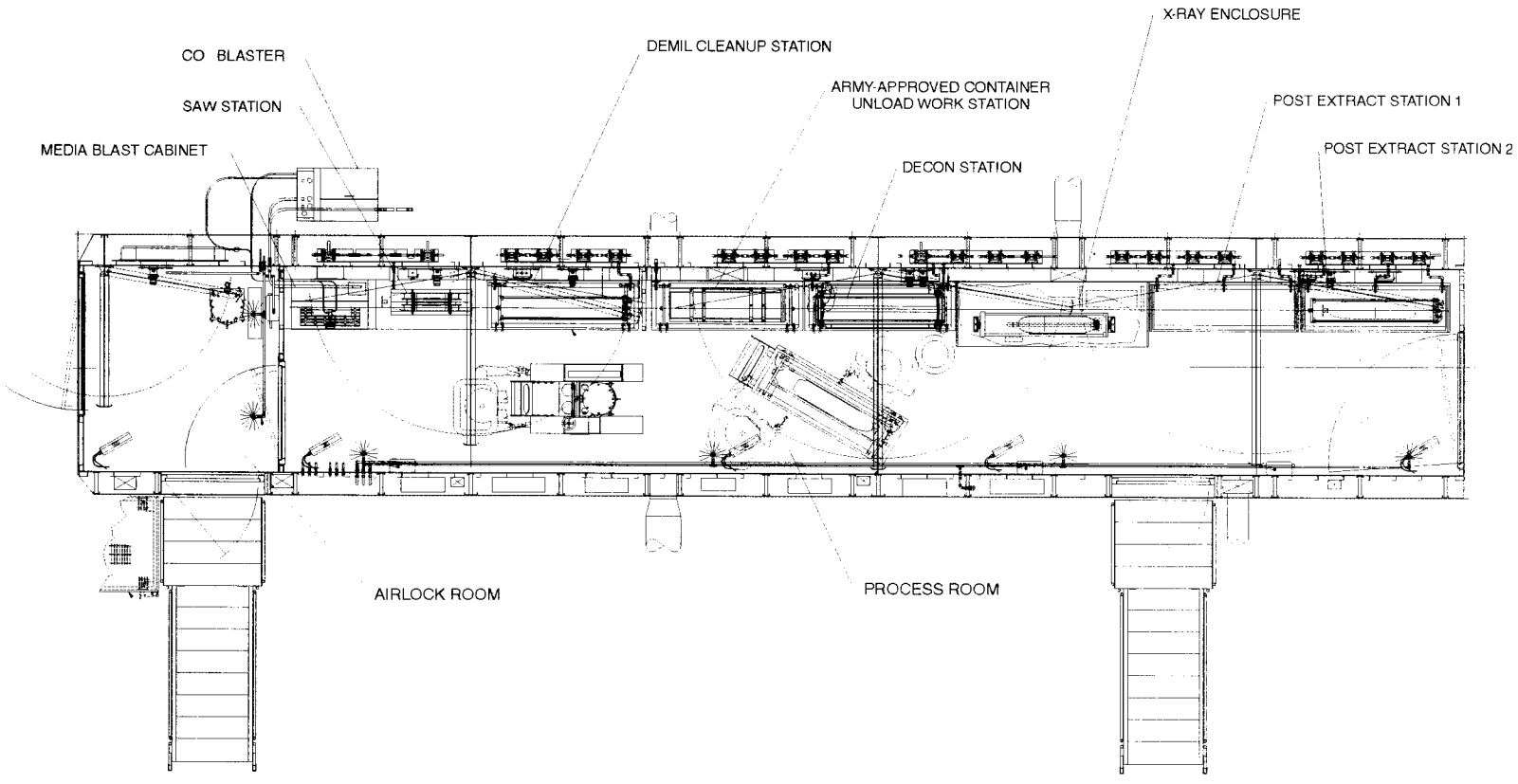


Figure 2-12. Unpack Area Trailer

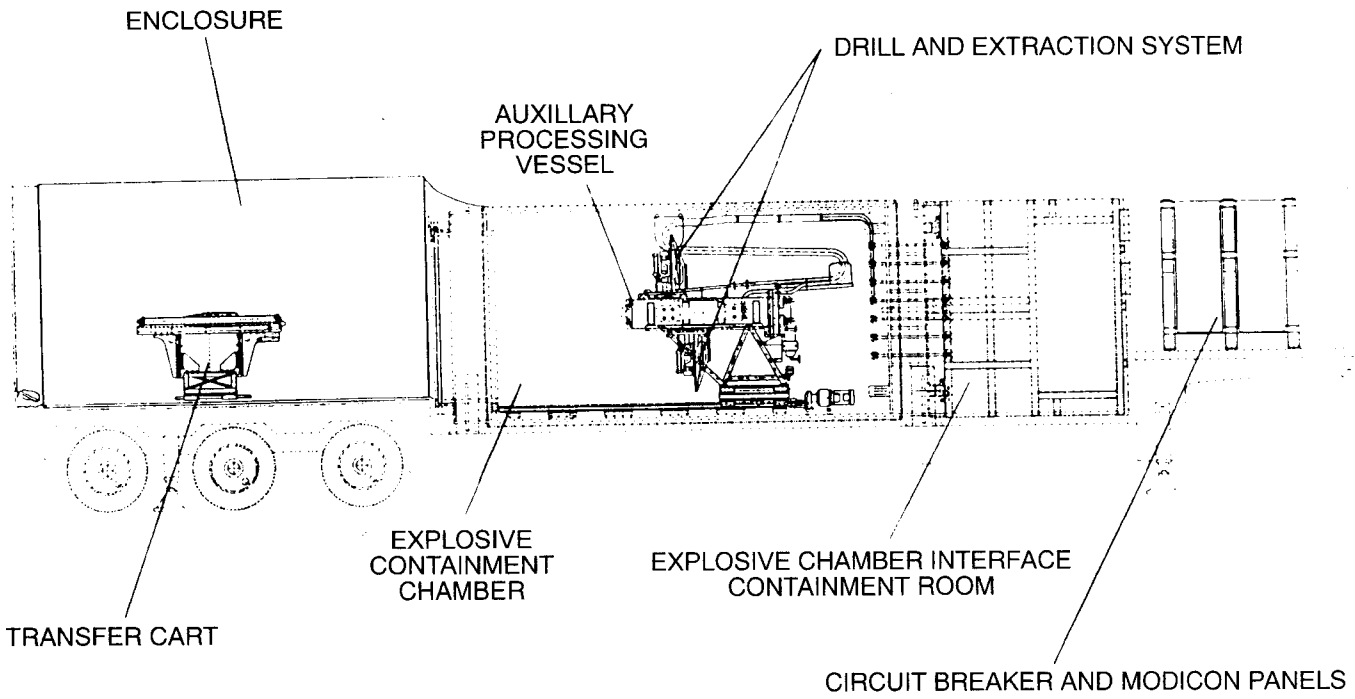


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Figure 2-13. Explosive Containment Chamber Trailer

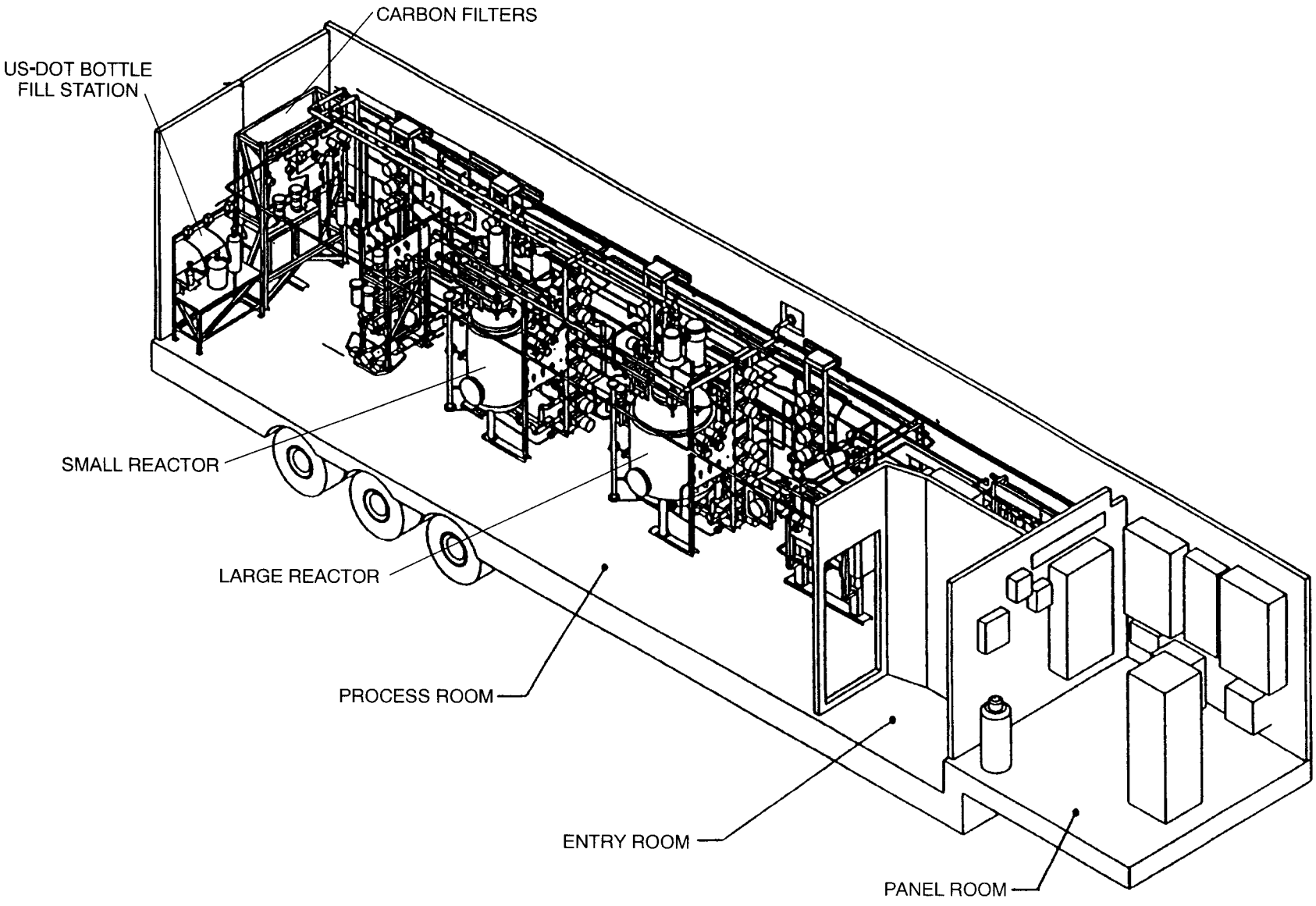


Figure 2-14. Chemical Processing Trailer

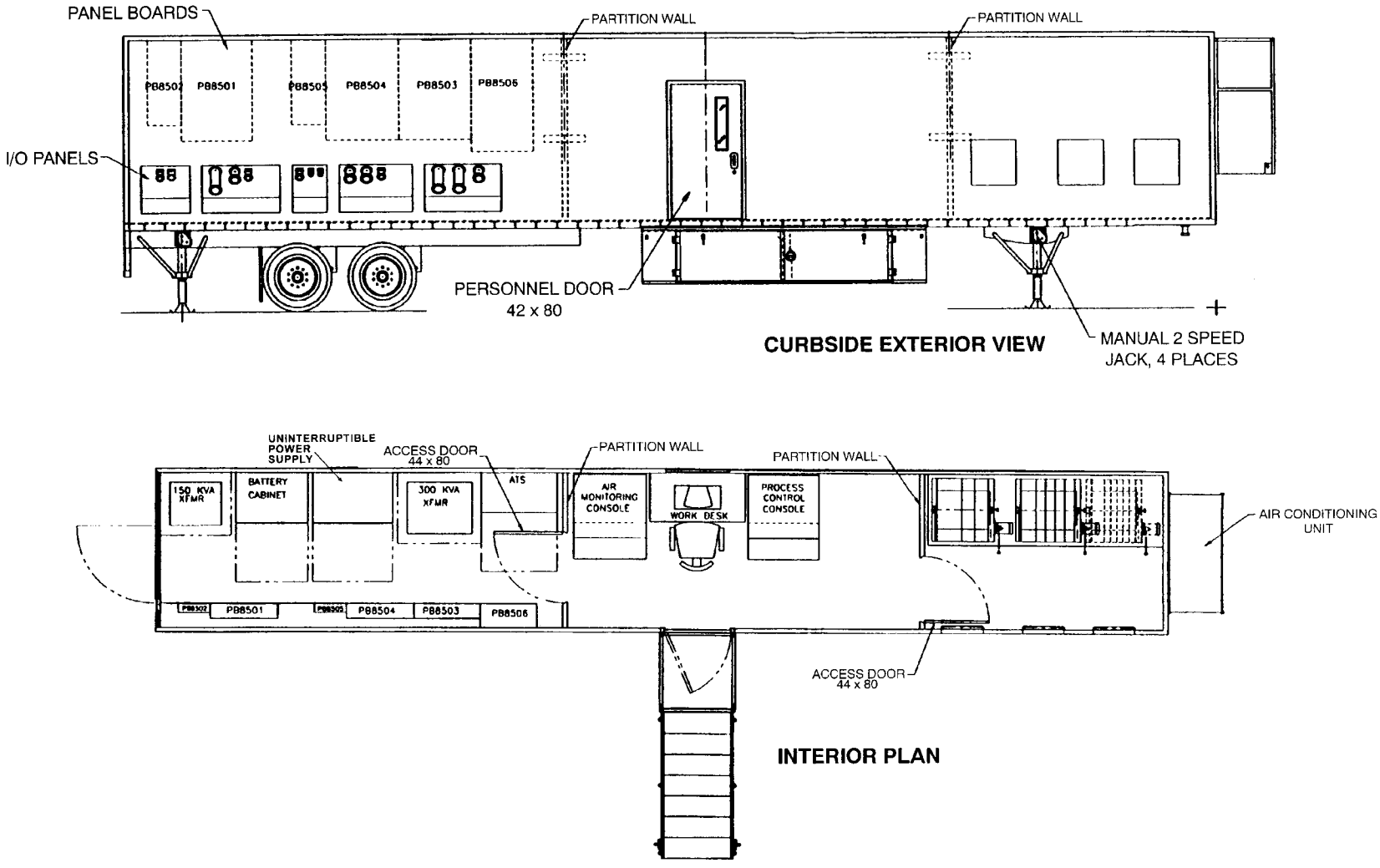


Figure 2-15. Control Trailer

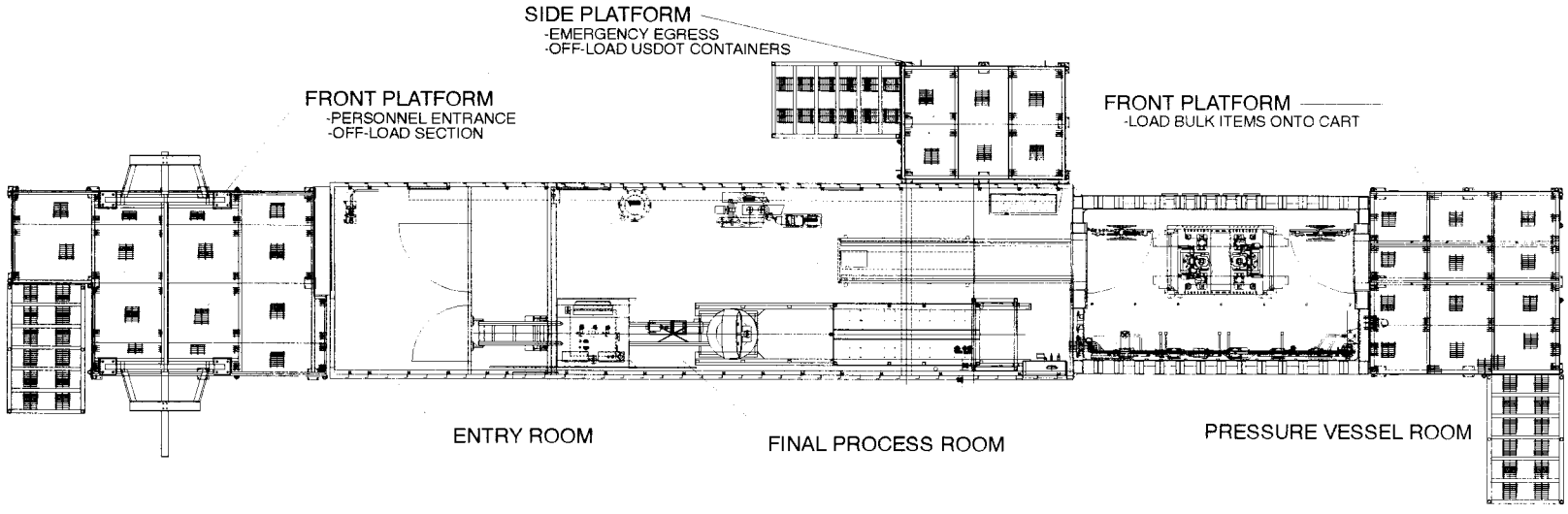
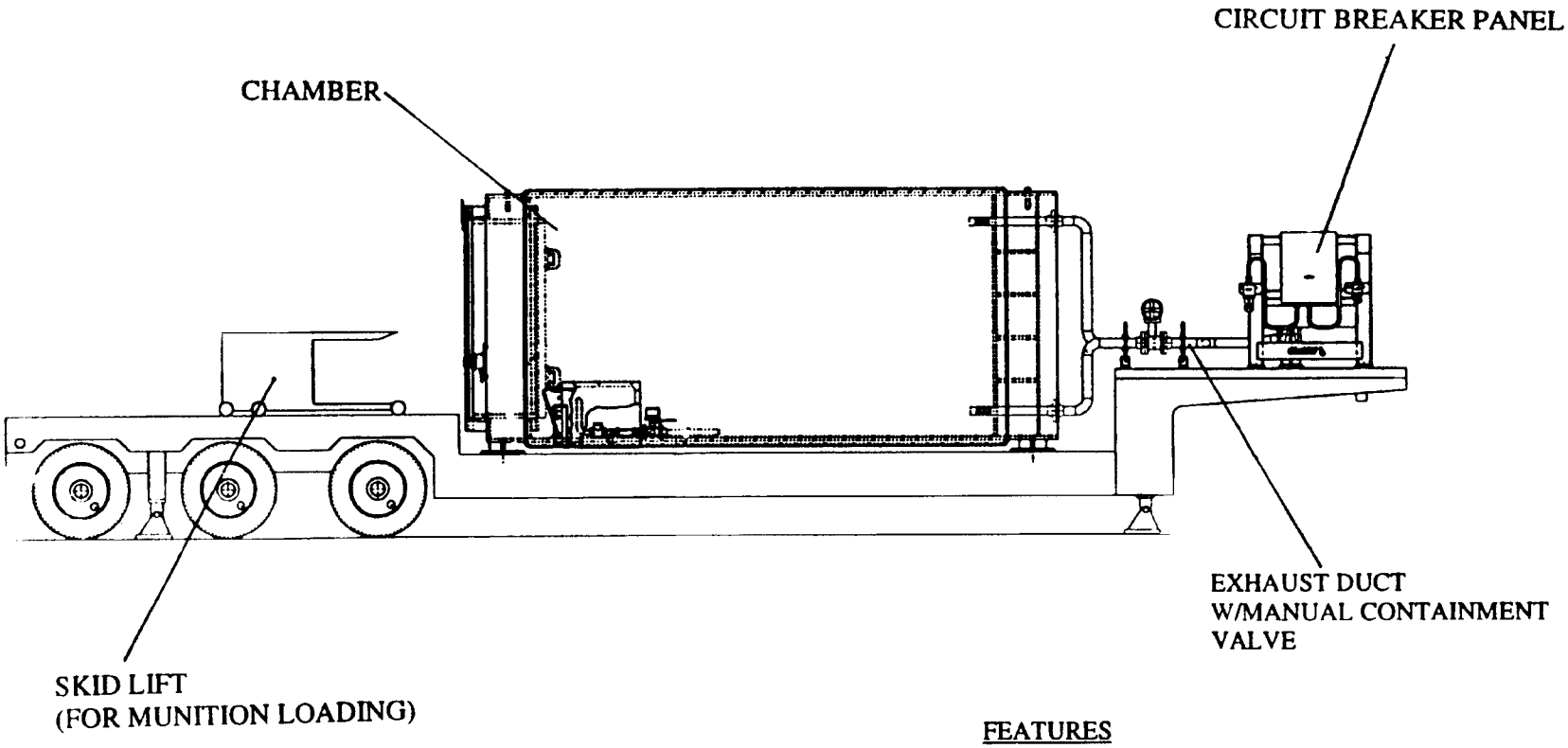


Figure 2-16. Bulk Item Accessing Equipment Trailer



FEATURES

- CHAMBER SIMILAR TO ECC W/ADDITIONAL FRAGMENTATION CONTAINMENT
- MANUAL CONTAINMENT VALVES W/POSITION INDICATORS
- SEPARATE VENTILATION AND FILTRATION SKID

Figure 2-17. Detonation Chamber Trailer

The chemical fill drained from the item would be transferred through piping from the explosive containment chamber to a reactor vessel in the chemical processing system trailer. If the chemical fill were chemical agent, it would be mixed with the appropriate treatment reagent pumped from the chemical supply trailer. If the chemical fill were an industrial chemical, it would be transferred without treatment into containers.

The chemical neutralent in the reactor vessel would be sampled to make sure the reaction was effective. If not, additional reagent would be added. If completed, the waste would be pumped to a neutralent holding tank in the chemical processing trailer, where it would be held temporarily. The neutralent would then be pumped to the neutralized waste system trailer where it would be collected and sampled. The wastes would finally be transferred either to an intermediate bulk container in the temporary waste storage area or directly to waste tanker trucks for shipment to a commercial waste treatment facility.

Drained munitions and containers would be returned to the unpack area trailer where they would be decontaminated and monitored to ensure adequate decontamination.

If the item were to contain explosive components, it would then be taken to the detonation chamber trailer where it would be detonated. The metal fragments and explosive residue would be collected, containerized, characterized, and temporarily stored pending further treatment, as required, and disposal.

Items without explosive components would be processed in the unpack area instead of being sent to the detonation chamber.

2.3.2.2 Bulk Items Greater than 20 Centimeters in Diameter

Large bulk items would be processed and drained in the bulk item accessing equipment trailer. The chemical fill drained from the item would be transferred to the chemical processing system trailer for treatment such as with the small munitions. If the fill were an industrial chemical, it would be transferred without treatment directly into waste containers.

When the bulk item is fully drained, it would be rinsed, sectioned, and decontaminated. The resulting metal parts would be sent to a waste storage area pending disposal.

2.3.3 Process Waste Disposal

The process wastes held in the waste neutralization trailer would be transferred either to a bulk container in the temporary waste storage area or directly to waste tanker trucks for shipment to a commercial waste treatment facility. Additional wastes generated at the site are described in Section 3.1.10.

2.3.4 Site Operating Requirements

The MMD-2 could be set up and operated on about 3 acres (1.2 hectares) of land. Approximately 40 people would be needed to assemble and set up the system, which could take up to 2 months. Up to 40 people would be needed to operate the systems.

Existing potable water and wastewater disposal systems would be used if available. Portable systems would be used if existing systems were not available. Existing electric utility systems would be used to supply power to the site.

2.4 Explosive Destruction System

The EDS, a transportable treatment system to process CWM with and without explosive components, would be used in two ways. The system would be used for CWM with explosive components that are unsafe for routine handling and transport. The system would also be used to treat certain types of CWM with and without explosive components under more routine conditions. In the EDS, the munition would be intentionally detonated to remove the explosion hazard of the munition and to access the chemical fill contents for treatment. The system could treat projectiles and mortars up to about 8 inches (20 centimeters) in diameter. See Appendix C.4 for more information on the EDS.

There would be two models of the EDS: Phase I and Phase II. The EDS Phase I model would be capable of safely withstanding a total explosive detonation of approximately one pound of trinitrotoluene (TNT) equivalent. The EDS Phase II could safely withstand a total explosive detonation of approximately three pounds of TNT equivalent. Total explosive content means all of the explosives inside the treatment chamber; this includes the shaped charge placed on the munition and the burster and fuze (if present) contained in the munition.

The EDS would be a stand-alone system requiring no additional support equipment and systems. The system could be transported by means of ground, water, and air.

An important use for the system would be when a CWM item with explosive components is discovered and a military ordnance disposal team determines that the item cannot be safely handled and transported to storage or to treatment in an MMD-2. The system is also being evaluated for use as a cost-effective alternative to deploying other treatment systems.

The EDS is still in design and development. To date, a prototype of the EDS Phase I has been used to test munition accessing. Chemical agent simulants and phosgene have been used in these tests as the chemical fills in the munitions.

The chemical neutralization employed in the EDS is similar to that to be used in the MMD-1 and MMD-2. In the neutralization process, the appropriate reagents would be pumped into the EDS vessel. The EDS vessel would be heated and agitated to mix the contents and thus would allow the neutralization reaction to proceed.

2.4.1 Components

The final design of the EDS is currently under development. Table 2-5 list several components that would likely be a part of the final system.

2.4.2 Treatment Operations

The EDS would treat only one munition at a time. The munition would be placed in the EDS vessel. Shaped charges would be placed on the munition that, when detonated, would (1) detonate the munition explosive charge or (2) open the munition to release the chemical fill if the munition explosive charge fails to detonate.

After detonation, the vessel would be cooled to reduce the pressure inside the vessel from the detonation gases. A vapor sample would be taken to confirm the identity of the chemical fill contained in the munition.

The appropriate chemical neutralization reagents would be added to the vessel and the vessel heated and agitated to ensure the reaction is completed. Liquid and vapor samples would be taken to determine treatment effectiveness. The liquid wastes would be transferred to appropriate containers, temporarily stored, and transported to a commercial treatment facility for additional treatment (as required) and disposal. Metal fragments would be collected, analyzed for contaminants, decontaminated (if required), placed in containers, and transported for additional treatment (if required) and disposal.

Table 2-5. Components of Explosive Destruction System

Component	Description
Explosive Destruction System Vessel	The EDS explosive containment vessel would be a stainless steel cylinder with reinforced end plates mounted on a truck trailer. The vessel would be capable of containing all fragments, liquids, and vapors after detonation of the munition. The vessel would be equipped with electronic firing devices, vapor sampling lines, and piping to convey liquids and gases.
Control System	All detonation and treatment operations would be controlled from outside the EDS vessel. Since design details depend on the treatment process used, the control system will be developed as system testing proceeds.
Utility and Support Systems	The utility and support systems for the EDS will be designed later in the development process. It is likely that electricity will be supplied by existing sources or from a portable generator.

2.4.3 Process Waste Disposal

All process wastes from the EDS vessel would be transferred to appropriate sealed containers and characterized as required by RCRA. Wastes that could possibly be contaminated with chemical agent would be sampled and analyzed for chemical agent concentration. Additional wastes are described in Section 3.1.10.

2.4.4 Site Operating Requirements

All resources needed to operate the EDS have not yet been identified. Only a small land area would be required. Personnel requirements for assembling and operating the system have not yet been determined. Existing potable water and wastewater disposal systems would be used if available. Portable systems would be used if existing systems were not available. Power would be supplied to the site from an existing electric utility system or a portable generator.

2.5 Storage Facilities

Non-stockpile CWM items already recovered or that would be recovered in the future from burial sites or test and firing ranges will be stored until a transportable treatment system is made available to treat the items. These will be stored in interim holding facilities or in existing storage facilities. These facilities are described below.

2.5.1 Interim Holding Facilities

The Army has designed and acquired portable buildings, called interim holding facilities (IHFs), that can be used to store recovered CWM at locations where a suitable existing facility is not available. Two sizes are available: 38 yd^3 (29 m^3) and 64 yd^3 (49 m^3). Figure 2-18 shows a conceptual site layout for an IHF site.

The buildings have a containment sump under the floor. Ventilation would be passive through louvered vents located on each end of the building. The louvers would be controlled from outside the building. Two monitoring ports would be located on the side of the building with the entry door. The buildings would have self-actuating chemical fire suppression units.

The building would be anchored to a pad. The clear area around the building would be at least 50 feet (15 meters) wide and would be kept clear of all trees and vegetation that could sustain a fire. Any grass in the clear area would be mowed regularly. Lightning protection would be installed if the stored CWM were flammable or known or suspected of having explosive components.

The following security features would be used at a site:

- Fencing and/or barriers to prevent unauthorized or inadvertent entry (usually a 6-foot [1.8-meter] high wire mesh fence on posts anchored in concrete).

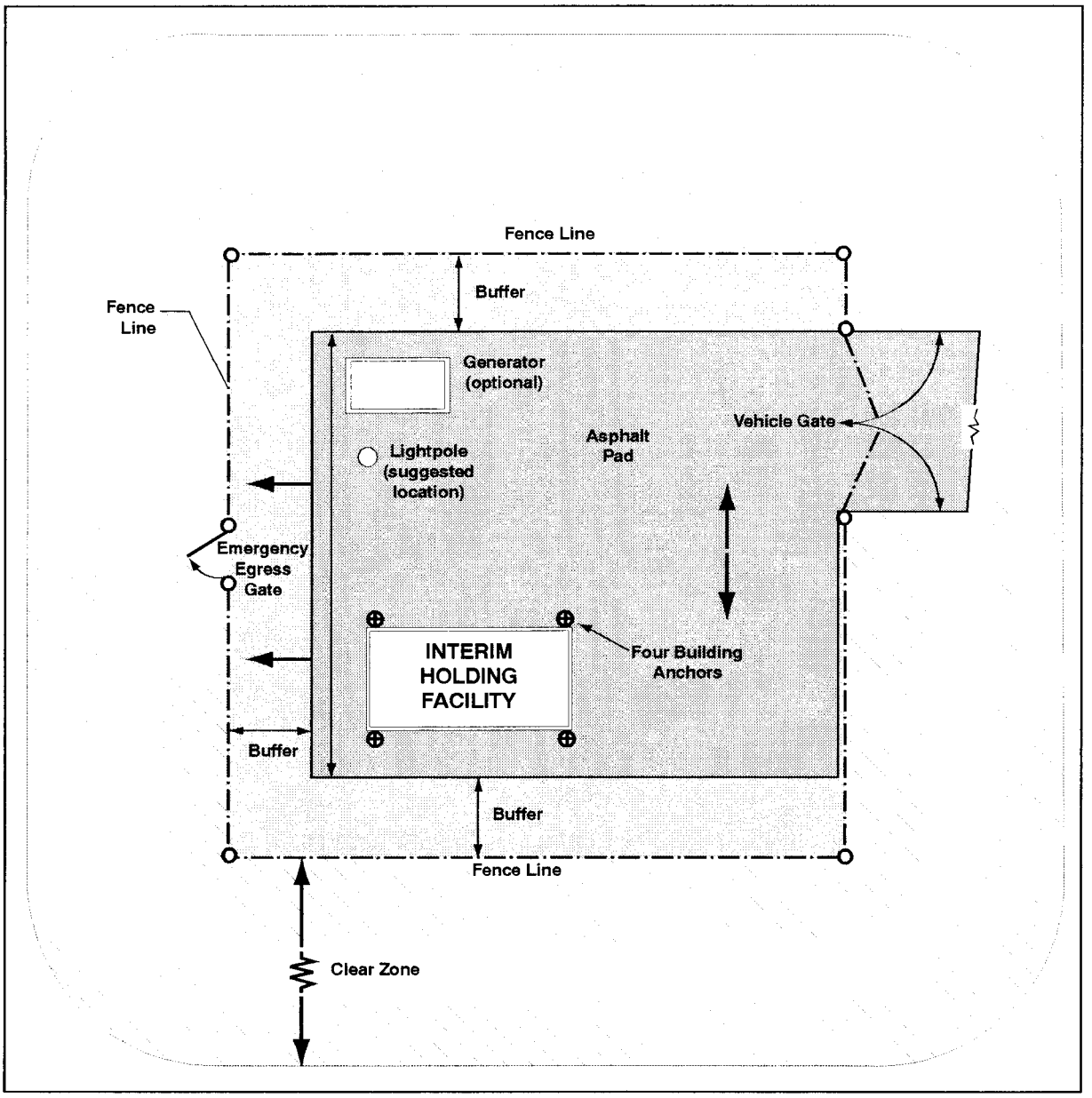


Figure 2-18. Conceptual Layout of a Portable Interim Holding Facility

- Exterior lighting at the door and on a pole on the site.
- Signs at the gate and on the fence stating the area is restricted, dangerous, and that unauthorized entry is illegal.
- Signs indicating that radios are not allowed if the building contains items with explosive components.
- Access controls when items are transferred into or out of the building.
- Gates and doors locked when entry access control is not being used.

The IHF would be operated in accordance with a site-specific plan and RCRA or CERCLA requirements. Minimum requirements when storing non-stockpile CWM items include the following:

- All items stored would be overpacked in an NSCMP-approved container.
- All overpacks would be monitored before being placed in storage.
- Items would not be stacked while in storage.
- IHF would be inspected before placing any item in it, and the record would be maintained in the facility.
- When containing items, an IHF would be locked and entry would be restricted to cleared and trained personnel.
- Appropriate manifests as required by RCRA would be used when items are received or shipped.

Several types of monitoring of an IHF would be also conducted. These are surveillance monitoring, first entry monitoring, and contingency monitoring.

Surveillance monitoring using sensitive monitoring devices would be conducted at least quarterly according to a site-specific plan. The purpose of this monitoring would be to detect leaking items and to ensure that air concentrations of chemicals are less than workplace exposure levels.

First-entry monitoring would be conducted whenever an IHF is entered. The monitoring would be conducted remotely, and confirmation monitoring would also be carried out.

Contingency monitoring would be conducted during an emergency contingency action. Such an action could be the detection of a release during surveillance monitoring or after an event that could possibly cause a release, such as severe weather or an earthquake that could damage an IHF or a stored item.

2.5.2 Other Storage Facilities

Existing ammunition magazines and igloos are storage facilities that could also be used to store non-stockpile CWM items. Magazines are aboveground buildings constructed of cinder block or other noncombustible material. Igloos are steel or cast-in-place arched enclosures that are covered with earth. Existing facilities could require modification to be used to store non-stockpile CWM items. Modifications could include sealing drains, modifying ventilators or ventilation systems so that they can be closed, and installing monitoring ports so the interior of the building could be monitored or sampled without requiring personnel to enter. RCRA or CERCLA requirements must be met. Clear zones, security equipment and procedures, monitoring, and maintenance at an existing facility would be the same as for an IHF, described above.

2.6 Storage Containers

Recovered non-stockpile CWM items would be placed in sealed containers called overpacks. These containers are metal can-like containers large enough to hold a CWM item and cushioning material. In the past, the following containers have been used for CWM items:

- Propellant containers designed to ship and store propellant for firing artillery projectiles
- CAIS shipping containers (pigs)
- Single-round containers designed for 155-millimeter and 8-inch projectiles

Single-round containers and similar containers meet USDOT and Military Traffic Management Command requirements for transporting CWM, provide long-term storage capability, and could be transported by air. Usually, only one item would be packed in a single-round container.

The Army has also designed and acquired overpacks for CWM, referred to as Army-approved containers. The uses and sizes of these containers are given in Table 2-6. Figure 2-19 is an example of an Army-approved container.

2.7 Monitoring Systems

Monitoring systems would be operated to ensure the safety of site workers, the public, and the environment. Near real-time monitors and confirmation and historical monitors are the two types of monitors that would be used. See Appendix C for specific location of monitoring systems in each treatment system.

Table 2-6. Use and Sizes of Army-Approved Containers for Non-Stockpile Chemical Warfare Materiel

Use	Dimensions			
	Inches		Centimeters	
	Inner Diameter	Length	Inner Diameter	Length
Overpack recovered CAIS items and recontainerization of chemical fills not to be treated in transportable systems	6.6	26	16.8	66
4-inch mortar shell 4.2-inch mortar shell 75-millimeter projectile 155-millimeter projectile 4.7-inch projectile 2.36-inch rocket	7	27	17.8	68.6
Livens mortar shell 155-millimeter projectile 175-millimeter projectile 8-inch projectile	9	41	22.9	104.1
Overpack CAIS items in pigs 100- to 125-pound bombs	12 (outer diameter)	56	30.5 (outer diameter)	142.2
500- to 1,000-pound bombs	21	79	53.3	200.7
1-gallon (3.8-liter) container M23 land mine	16.5	5.5	41.9	14

CAIS – Chemical agent identification sets

2.7.1 Near Real-Time Monitoring System

Near-real time monitoring would be done by using a MINICAMS ® monitoring system. The monitoring system uses gas chromatography to detect airborne concentrations of agents (HD, HN, VX, sarin, and Lewisite), and industrial chemicals (chloroform, phosgene, cyanogen chloride, and chloropicrin) that may be above workplace exposure limits. A MINICAMS ® is an automated gas chromatograph that operates by alternating between sampling and analysis cycles. During the sampling cycle, a vacuum pump pulls an air sample into the MINICAMS ® through a solid sorbent tube or into a sample loop where the analytes are collected. Heated sample transfer lines ensure that chemical materiel being transported down the sample line does not condense or become absorbed onto walls of the sample line. An alarm would sound when a chemical concentration in the air is detected greater than a set amount.

Figure 2-19. Example of an Army-Approved Container

A number of MINICAMS® would be used in the transportable treatment systems and facilities. The MINICAMS® would be configured to detect sulfur mustard, sarin, VX, phosgene, and other chemical agents and industrial chemicals that would be treated or repackaged.

2.7.2 Confirmation and Historical Monitoring

Depot ambient air monitoring stations (DAAMSs) would be used to conduct confirmation sampling in the event of a MINICAMS® alarm and historical monitoring where MINICAMS® is not used. A DAAMS consists of a vacuum pump, a sequencer, and sample tubes. The vacuum pump continuously draws air through glass tubes packed with a solid sorbent material to trap airborne contaminants. Each DAAMS station has a series of tubes, and the station sequencer allows the sample sets to be collected in rotation for uninterrupted monitoring. Each tube within the DAAMS is used to monitor for a particular kind of chemical agent. After the DAAMS samples are collected, they are analyzed using a gas chromatograph.

Colorimetric tubes would be used to confirm the presence of industrial chemical vapors in case of a MINICAMS® alarm. A colorimetric tube sampling system consists of a sample tube and a pump. The pump is used to draw a known volume of air into a tube. Each colorimetric tube is designated for a specific industrial chemical; the tube contains a chemical sorbent that changes color when exposed to the specific chemical materiel or class of chemical materiel. The length of the color change within the tube equates to a concentration of the specific chemical in the air. The colorimetric tubes would not be placed in a sample station like the continuous monitors, but they would be used to sample air in the same location as the MINICAMS®.

Section 3

Alternatives

The Army has considered several alternative ways to implement its mission requirement to treat and process the non-stockpile CWM considered in this environmental impact statement (see Table 1-1). Alternatives considered have included using transportable treatment systems, constructing fixed systems at each site, using facilities designed and constructed to destroy stockpile CWM, using commercial treatment facilities, using other types of treatment methods, and the no-action alternative (required by the National Environmental Policy Act). Two alternatives are analyzed in detail in this environmental impact statement: the transportable treatment systems alternative (the preferred alternative; described in Section 3.1) and the no-action alternative (described in Section 3.2). The other alternatives are not analyzed further. Section 3.3 describes why these alternatives are not being given further consideration.

The preferred alternative is to complete the development of the four types of transportable treatment systems described in Section 2 and Appendix C so that they would be available to be deployed in the field in the future as required to process and treat non-stockpile CWM. The Army would also continue to review and assess other treatment technologies, methods, and processes for treating CWM and disposing of treatment wastes. Section 3.1 describes the activities that would take place in the future if this alternative were selected.

In the no-action alternative, the Army would suspend or discontinue the development of the transportable treatment systems and continue to review and assess other treatment technologies and methods until one or more is developed and made available to be deployed in the field to treat non-stockpile CWM. While the Army continues to review and assess other treatment technologies and methods, the U.S. Army Corps of Engineers or specific military installations would continue storing and maintaining recovered non-stockpile CWM that is currently in storage and would place into storage any non-stockpile CWM recovered in the future from burial sites or firing and test ranges (see Sections 1.8 and 1.9). Section 3.2 describes the activities that would take place if this alternative were implemented.

Section 3.4 compares the potential environmental impacts of the preferred alternative and the no-action alternative. The impacts summarized in Section 3.4 are described in detail for the preferred alternative in Section 5 (normal treatment operations) and Section 6 (accidental releases of hazardous substances) and for the no-action alternative in Section 7.

Many activities would take place at CWM burial and storage sites before transportable treatment systems would be deployed to process and treat these items. Section 1.9 describes these activities, which would occur regardless of the alternative the Army implements and are the responsibility of DoD organizations other than the NSCMP (see Section 1.8).

The Army is only deciding at this time whether the four transportable treatment systems currently undergoing final development and testing should be completed so that they would be available for field deployment. The Army is not deciding how and where these systems would be deployed to treat and process items at specific CWM burial or storage sites. These would be site-specific decisions that would be made separately in the future for each location only after additional environmental review, public involvement, and consultation with the appropriate federal, tribal, state, and local authorities.

3.1 Preferred Alternative

The preferred Army alternative is to complete development and testing of the four transportable treatment systems described in Section 2 and Appendix C to make them operational so that they would be available to be deployed in the field in the future with appropriate support equipment, facilities, and personnel as required to treat non-stockpile CWM. The Army would also continue to review and assess the CWM treatment potential of other technologies, methods, and processes such as those considered in the Assembled Chemical Weapons Assessment Program and the Alternative Technologies and Approaches Program. Some of these other technologies, methods, and processes are described in Appendix G. The Army would also continue to review and assess methods and technologies to treat wastes from the transportable treatment system. As methods appear feasible in the future, the Army would determine their suitability for wastes within adequate health, safety, and environmental protection requirements.

If the Army selects the preferred alternative, transportable treatment systems would be available to be deployed to locations determined in the future on a site-specific basis to process and treat CWM currently in storage or recovered from burial sites. Such deployments would only take place after additional environmental and other review and consultation with regulatory authorities and the public. Chemical warfare agents would be treated in the transportable systems with chemical reagents that break down the chemical warfare agents into less hazardous compounds that would be similar to other industrial hazardous wastes. In this state these liquid neutralent wastes could be safely shipped to commercial TSDFs for handling and disposal like other industrial hazardous wastes. Industrial chemicals contained in munitions and CAIS (with the possible exception of phosphene) would be repackaged in the transportable systems into appropriate shipping containers and transported to a TSDF for treatment and disposal. Phosgene may be treated in some of the systems, as described in Section 2.

Described below and shown in Figure 3-1 is the life cycle of activities that would take place if the Army selects the preferred alternative and a future decision is made to deploy a treatment system to a field location to process and treat non-stockpile CWM. The life cycle involves selecting the location at which the treatment system would be set up and operated; transporting the system to the site; setting up and testing the system; transporting CWM to the system for treatment; operating the system to process and treat CWM items;

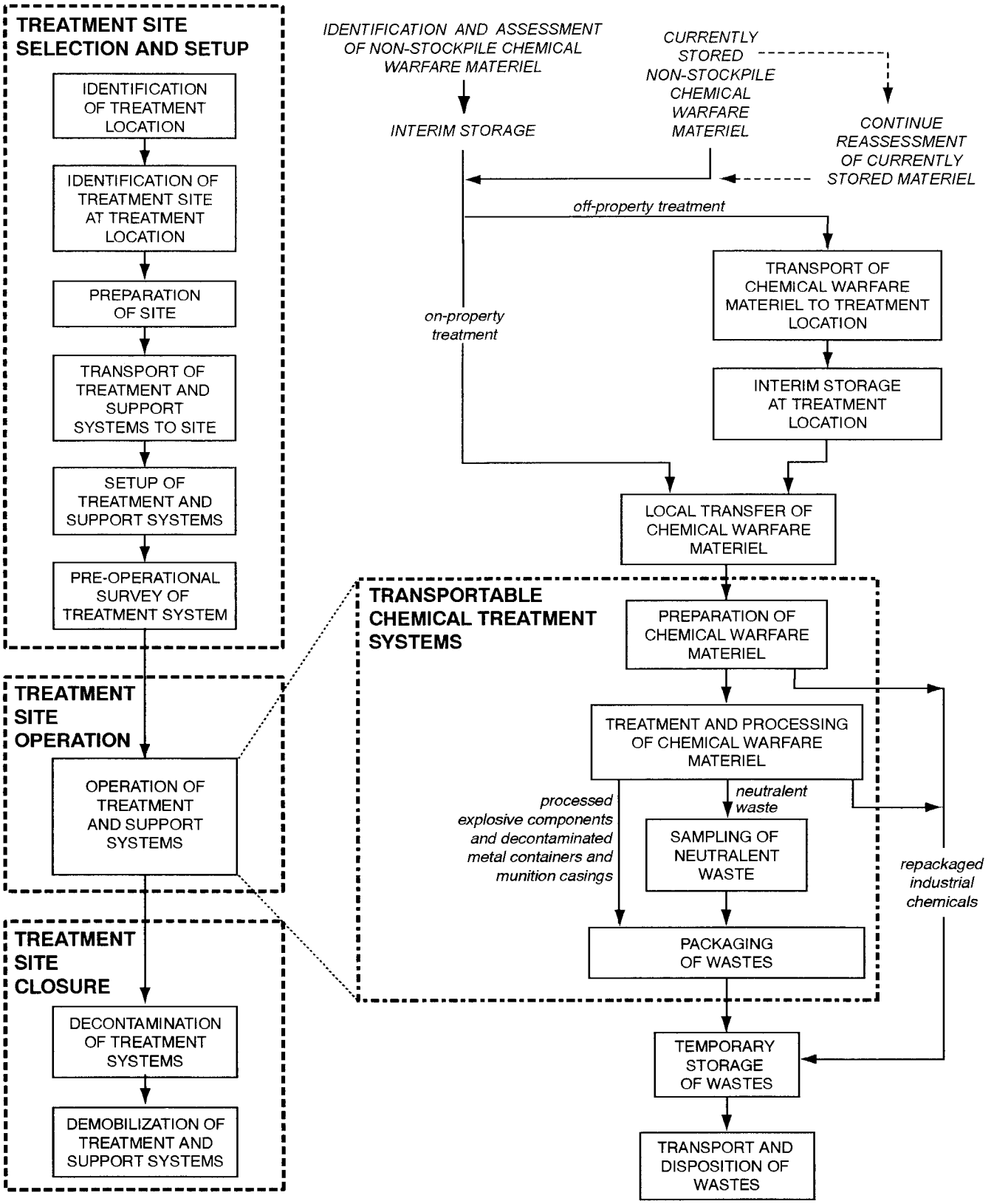


Figure 3-1. Activities for Selecting and Operating a Treatment and Processing Site

decontaminating, cleaning, demobilizing and removing the system from the site when operations are completed; closing the site; and disposing of all wastes. For convenience, all waste management methods and activities for all life-cycle stages are described in Section 3.1.10. The possible environmental impacts of these activities are analyzed in Sections 5 and 6.

The decisions associated with the life-cycle activities described below are not being made by the Army at this time. These decisions are site-specific decisions that would be made in the future only after additional environmental and other review and analysis and public involvement. The life-cycle activities are described only as the basis for the environmental impact analysis of the preferred alternative presented in Sections 5 and 6.

3.1.1 Location of the Treatment System

The transportable treatment systems would be deployed to a location determined to be most suitable for processing and treating CWM recovered or stored at a specific location. The treatment site location could be located on the military installation or other property where the CWM items are stored or buried or to a location elsewhere.

Laws restrict where non-stockpile CWM can be moved to if the items are not to be treated on the property where they are located (see Section 1.6). CWM cannot be moved outside of the state in which it is stored or recovered unless it is being moved to the nearest CWM stockpile storage facility that has a permit to receive and store the CWM.

The appropriate DoD authority would conduct a site-specific analysis as part of the site-selection process. A variety of factors would be considered, such as public safety, laws, operating logistics, available infrastructure, cost, and environmental impacts. The final decision would be made in conjunction with appropriate federal, tribal, state, and local officials. These organizations would include USEPA, and Indian Tribes and state agencies that have regulatory authority for CWM burial sites remediated under CERCLA or RCRA. Public input and comment would also be part of the site-location process.

The NSCMP and other DoD organizations would provide support in the treatment site location process. The NSCMP would identify those site requirements necessary to support the transportable treatment systems, based on the suspected types of non-stockpile CWM to be recovered or those presently stored at a site.

Three general factors would be considered when selecting a treatment location site. The factors would be considered not only to ensure that an appropriate site is selected, but also to identify those actions that would have to be taken as part of site preparation activities. The following factors would be considered:

- Proximity and density of population surrounding a site and how the hazard area needed at the site would affect this population

- Physical requirements and infrastructure needed
- Site environmental conditions

3.1.1.1 Hazard Zone

In identifying a suitable treatment site, a maximum credible event would be postulated for hazardous chemical operations expected to occur at a site. Army Regulation 385-61, *The Army Chemical Agent Safety Program*, defines a maximum credible event as a "worst case" accident scenario that results in the release of chemical agent that has a reasonable probability of occurrence. A hazard zone and the risks to the surrounding local populations are then calculated based on the concentration of the release should the maximum credible event occur. Based on the calculated hazard zone and risks, the population in the area surrounding the site would be identified to determine whether any persons reside or work in the high risk portion of the hazard zone (Department of the Army, 1997a). If any persons reside or work in the high risk portion of the hazard zone, either the population would need to be evacuated during operations, a different site would need to be identified, or additional mitigation actions would need to be taken to reduce the frequency or severity of the maximum credible event.

3.1.1.2 Physical Site Requirements and Available Infrastructure

The following physical requirements of a specific site would be considered:

- Whether a site has sufficient land area for the setup and use of the transportable treatment and support systems, for IHFs or storage facilities if not already in use as part of recovery activities, and for waste staging areas
- Whether site soil characteristics are capable of supporting the weight of the transportable chemical treatment and support systems
- Whether the site is level
- Whether the site is located on or near geologic or other conditions that could potentially affect the safety of operations, such as fault and calcareous zones (for example, areas subject to the formation of sinkholes) and floodplains

Where existing and available buildings could be used instead of an environmental enclosure (for example, for MMD-1 operations), the physical characteristics of the buildings that would be considered would include the following:

- The capability of building floors to support the weight of the systems to be operated in the buildings
- The structural integrity of the buildings and the standards to which the buildings were constructed relative to seismic and other hazardous conditions
- The ability to modify buildings to perform the same functions as the environmental enclosure

In addition to the physical requirements of a site, the deployment and use of transportable chemical treatment and support systems would require specific support services that could be met in a variety of ways. The following factors would be considered in identifying a site:

- Roadways of sufficient design and capability to enable (1) the delivery of transportable chemical treatment and support systems to the site, (2) the delivery of supplies required to operate the transportable chemical treatment and support systems, (3) transport of non-stockpile CWM items to the transportable chemical treatment and support systems, and (4) transport of wastes generated during the processing and treatment of non-stockpile CWM.
- Proximity to water, sewer, and electrical power supply systems required during operation of the transportable chemical treatment and support systems.
- Physical security arrangements and availability of security personnel for response.
- Arrangement for emergency response forces including fire and medical personnel.
- Proximity to, or arrangements for, medical support facilities capable of treating industrial and chemical agent casualties.
- Availability of existing storage facilities and waste staging areas for temporary storage of non-stockpile CWM and waste generated from CWM processing and treatment operations.
- Housing or billeting and services to support setup and operational personnel.

3.1.1.3 Environmental Conditions

Environmental conditions of a site and surrounding area would be considered on a site-specific basis. The analysis would include the appropriate environmental review as required by the National Environmental Policy Act and Army Regulation 200-2. The site-selection process would involve public involvement and comment.

Background sampling of site air and soil would be carried out, as necessary, to ensure the selected site does not have sources of contamination that could interfere with monitoring activities performed as part of the operation of the transportable chemical treatment and support systems.

3.1.2 Types of Treatment Systems Deployed to a Treatment Location

Non-stockpile CWM sites are not all the same. Any site could have one, several, or all of the following types of CWM:

- Only CAIS items
- Only munitions without explosive components
- Only munitions with explosive components
- Munitions that may contain a fuze that could detonate during routine transportation or handling
- Sites with large (bulk) items
- Various combinations of CAIS, bulk, explosive, and non-explosive CWM items

The types of CWM items to be treated at a burial or storage location would determine which type of transportable treatment system must be set up and operated at the treatment location. Table 3-1 shows what treatment systems might be deploye d at different types of burial or storage sites.

3.1.3 Treatment Site Preparation

After identifying a specific site and obtaining all required approvals or permits, the site would be prepared to accept the transportable chemical treatment and support systems. Site preparation activities could include making physical alterations to a site or buildings, installing or modifying existing utility systems, and modifying roadways to enable transporting the systems to the selected site. All necessary arrangements for support services would also be completed.

Possible physical alterations to a site to accept the transportable chemical treatment and support systems could include the following based on site-specific conditions: (1) grading the site; (2) constructing pads with footings, if needed; and (3) clearing vegetation and trees (as needed) for a security zone around non-stockpile CWM storage facilities, processing and treatment systems for personnel movement between the systems, and transporting CWM and other materials into and out of the site. Possible physical alterations to buildings that would be used instead of an environmental enclosure for the treatment systems could include structural modifications to buildings, sealing building openings and penetrations, and installing fans to provide negative air pressure and a filter system. Installing or modifying existing utilities could include installing electric power lines, communication cabling, and extending water and sewer lines.

Erosion control measures and best management practices would be used in site preparation activities. Applicable building codes would be reviewed to determine anchoring requirements

Table 3-1. Factors Determining the Type of Treatment System Deployed to a Treatment Location

Site Contents	Description	Treatment System Deployed
Only CAIS items	CAIS were distributed to a large number of military units and supply depots to be used during training. After the sets were used in training or were no longer needed, a common practice was to bury the sets and any remaining components. Consequently, many sites with no production or manufacture of CWM or the testing or firing of chemical munitions may have CAIS or CAIS components buried on-site.	RRS
Only munitions without explosive components	Non-stockpile sites that may have CWM without explosive components would include (1) sites with CWM research facilities that have only used munitions or containers without explosive components; (2) sites with munitions or chemical samples that do not have explosive components; and (3) sites that were used for the disposal of CWM munitions that leaked during transport, which would be dependent upon the type of munitions transported (for example, chemical bombs and some larger projectiles were shipped without their fuzes or bursters installed).	MMD-1 or an MMD-2 or an EDS[a]
Only munitions with explosive components	Non-stockpile sites that may have CWM with explosive components would include (1) sites with test ranges or ranges that allowed static firing, firing from guns, or dropping of chemical munitions; and (2) sites that were used for disposal of munitions that leaked during transport.	MMD-2 or an EDS[a]
Munitions with unsafe fuzes	Some non-stockpile sites may have munitions that failed to function when fired or dropped. Such munitions may be considered armed and unable to be handled or transported in a routine manner without risk of detonation. Fuzed munitions manufactured in the World War I era, which were unarmed when buried and would not have been expected to detonate if moved, may now be armed because of deterioration of the safety pins. Some non-stockpile CWM munition chemical fills (for example, cyanogen chloride) may also undergo deterioration that could cause a violent rupture of munition casings.	EDS[b,c]
Bulk items	Sites may have large, nonexplosive, items that are too big to be processed in an MMD-1. These items include ton containers, bombs greater than 125 pounds, and some large storage bottles.	MMD-2 with bulk item accessing equipment
Various types of items	It is possible that a variety of types and quantities of non-stockpile CWM could be present at many sites. Several munitions testing facilities also had CWM firing ranges, and military units assigned to these facilities may have had CAIS items. At sites used in the past to dispose of different types of chemical munitions, disposal practices may have allowed the disposal of munitions with and without explosive components, as well as CAIS items. Current storage locations are presently storing several types of non-stockpile CWM.	An optimum combination of treatment systems would be identified.

[a]This option depends on the results of ongoing evaluations and future tests.
[b]Immediate emergency destruction may be implemented if the munition is determined to pose an immediate threat to safety.
[c]Safe items would be treated with an EDS or MMD-2.

CAIS – Chemical agent identification sets
CWM – Chemical warfare materiel
EDS – Explosive Destruction System
MMD-1 – Munitions Management Device–Version One
MMD-2 – Munitions Management Device–Version Two
RRS – Rapid Response System

for equipment or trailers, and footings for anchoring systems would be constructed as required by applicable codes. Security measures similar to those used for an IHF as described in Section 2.5 (for example, fencing and lighting) would be constructed around the treatment and processing area of the site. (Department of the Army, 1993b).

Local labor would be used for site preparation activities.

Wastes generated during site preparation are described in Section 3.1.10.

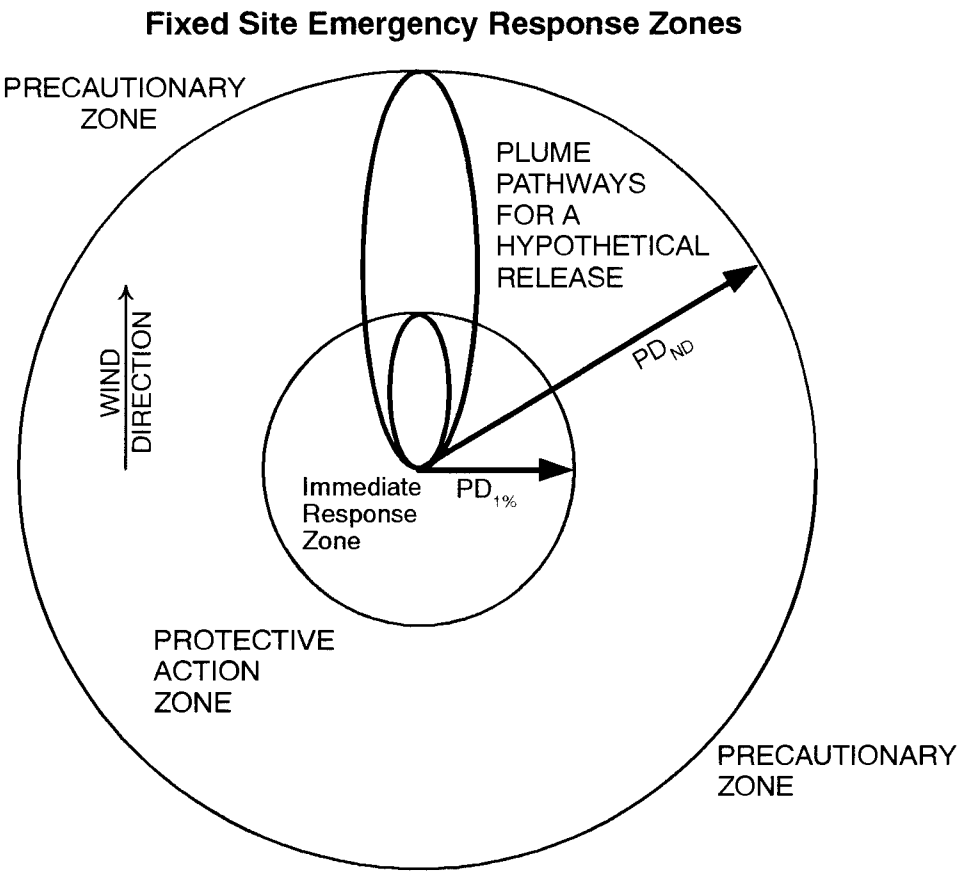
Arrangements would be finalized for emergency response, security, and medical support. An emergency response plan would be prepared for the treatment site in accordance with all applicable laws and regulations. The emergency response plan would provide specific instructions to be followed should chemical agent or industrial chemicals accidentally be released once agent handling, treatment, or processing operations were started at the site (see Section 3.1.8).

The area that could be affected by a release from the treatment site would be determined based on chemical concentration levels predicted using a plume dispersion model. An emergency planning zone (EPZ) would be determined, based on these predicted concentrations, to establish the area where the emergency response concepts would be applied. This zone would encompass a circle centered around the potential release point (see Figure 3-2). The radius of the EPZ would be determined by the exposure limit resulting from the maximum credible event (see Section 3.1.1.1) and would be highly dependent on the type and quantity of CWM that would be treated at the site.

Emergency response requires appropriate facilities, communication capabilities, and pre-established mechanisms for accident assessment and decision making. The level of effort would be determined based upon the amount and types of CWM that would be treated at the site. To facilitate communication between on-site personnel, off-site personnel, and public citizens, emergency operations centers (EOCs), both on-site and off-site would be established. The off-site EOC could consist of a State Emergency Response Commission and/or a Local Emergency Planning Commission, as defined under the Emergency Planning and Community Right-To-Know Act (EPCRA, 40 CFR 355).

The on-site hazard associated with treating the CWM would vary as CWM was treated at the site. The on-site EOC would be informed as to the current hazards at any specific time once agent operations were commenced (see Section 3.1.8) and would communicate the information to the off-site EOC on a daily basis.

The on-site EOC would have access to computerized dispersion modeling systems, supported by local meteorological stations, that could predict off-site areas potentially affected by a release and project concentrations that could occur in those areas. An accident classification system would be used that would allow for rapid characterization of a release. This would support timely decision making on the appropriate actions to be taken to provide



PD_{ND} - plume distance to no deaths
$PD_{1\%}$ - plume distance to one percent lethality

Figure 3-2. Emergency Planning Zone for a Transportable Treatment System Site

for public protection, including provisions for precautionary actions, automatic actions (for certain types of rapidly occurring events that require immediate public protection), and discretionary actions that involve specifying different protective actions for different locations based upon agent concentrations, meteorological conditions, and response times available.

The authority and responsibility for performing emergency response functions would be shared by the on-site command and local, state, and federal government, and/or tribal authorities, as appropriate. While the on-site command would be most knowledgeable of potential accident circumstances and effects, local, state, or tribal government authorities would be responsible for protection of the off-site population. Close cooperative relationships, including written agreements, would be established between the on-site command and the surrounding local government authorities so that appropriate actions could be implemented quickly and effectively for public protection. The emergency program managers, both on-site and off-site, would be trained and have regular interaction to maintain the ability to manage the emergency response to a chemical release.

The U.S. Army Medical Command (MEDCOM) could provide trained medical personnel for medical treatment in support of activities involving chemical agent. Should military medical personnel not be provided, then local medical professionals would be trained to identify and treat agent-related symptoms.

3.1.4 Treatment System Setup

Based on the chosen site, a transportation route would be selected for transport of the chemical treatment and support systems, and applications would be made for any required transport permits (for example, those based on size and weight).

The chemical treatment and support systems would be transported to the site by the most appropriate mode of transport. The RRS and EDS could be transported by road, rail, air, and water. The MMD systems could be transported to a site by road, rail, and water.

An environmental enclosure would be erected or suitable building modified as the first activity, except for an RRS, which does not need an environmental enclosure. Then, all components of the transportable chemical treatment and support systems would be assembled and connected to utilities (if available) and support services.

Equipment, tools, and supplies would be obtained and stored at the selected site in designated areas. These items would include compressed gas cylinders, treatment reagents, general purpose decontamination solutions, fuel for vehicles and generators, maintenance equipment and tools, lubricants, fixtures used to transport CWM items from storage or unpack area to the process area, cleaning materials, empty waste containers, personal protective equipment, emergency response equipment, replacement filters and other expendable supplies, and repair parts.

Wastes that could be generated during system setup are described in Section 3.1.10.

All areas where contamination from operating the treatment system is considered to be unlikely would be designated "support zones." An exclusion zone would be established in areas where contamination could occur. A contamination-reduction zone would be established between the exclusion zone and the support areas. All decontamination activities done outside of engineering controls would be done in the contamination-reduction zone. A personnel decontamination station or trailer would be located at the entrance of the contamination-reduction zone. Entry into and exit from the contamination-reduction zone would be controlled at all times once handling of non-stockpile CWM begins at a site (Department of the Army, 1997a).

The personnel who set up the system would be the operating personnel. These personnel would be Army contractor employees and would be assigned to the site without their families for the time period needed for site set up, operation, and decommissioning. They would live in motels or apartments rented by the contractor in the local area. If local housing is not available, the contractor would provide temporary housing in mobile quarters moved to the area for this purpose. Workers would commute daily to the treatment site. About 20 people could be required to set up an RRS. Up to 40 people could be required to set up an MMD-1 or MMD-2.

Setup and operating personnel would have received system-specific training on setup and operation of the treatment systems. Some subcontractors may be hired to assist in the systems setup. Subcontractor labor could be local personnel.

The time required for system set up could vary depending on the type of system. Up to three months could be needed to complete set up and the pre-operational survey.

3.1.5 Treatment System Pre-Operational Survey

After assembly of the transportable chemical treatment system and support equipment, all components of the system would be tested to ensure each works properly individually and as a system. When the operating contractor is ready to begin processing CWM, the Army would conduct a pre-operational survey before approving the start of processing and treatment operations. No chemical agent or industrial chemicals would be used during pre-operational surveys.

A team of people headed by Army personnel would conduct the pre-operational survey. Team members observe the operating personnel processing dummy rounds during normal operating conditions and simulated operating upset scenarios. Deficiencies are noted and discussed with the contractor. When the deficiencies are corrected to the Army's satisfaction, approval is given to the contractor to begin processing CWM.

Wastes generated during the pre-operational survey are described in Section 3.1.10.

3.1.6 Transport of Materiel to Treatment System

When the treatment system has been set up, tested, and approved for operation, CWM items would be brought from the storage or recovery location to the treatment system for processing and treatment. Specific transport activities would depend on whether the treatment system is located on the military installation or other property where the CWM items are stored or buried or if the system is located elsewhere. Details are given below. Wastes generated during transport operations are described in Section 3.1.10.

3.1.6.1 On-Property Transport

If the treatment system is located on the property where the CWM items are stored or buried, open-bed trucks (pickup or flat-bed truck) would be used to move CWM items overpacked in approved containers from the on-site recovery or storage location to the treatment system. The trucks would be loaded by hand or by using forklifts, dollies, or hand carts. The overpacked items would be secured in place on the bed of the truck using straps or wood bracing. Small items might be secured in place with sandbags.

Security and emergency response personnel would escort the transfer vehicle. Additional emergency response personnel would be available on-site with response equipment readily available.

If CWM items are stored in an IHF close to the treatment system, the items might be moved only by forklift, dolly, hand cart, or other handling device.

3.1.6.2 Off-Property Transport

Truck and/or military aircraft, depending on the distance, would be used to transport CWM items to a treatment location that was not located on the military installation or other property where the CWM items to be treated were located. Such transportation would require using public roads and/or airspace.

Local Transport by Truck. Transportation by truck on public roads to a nearby treatment site would be carried out only if air transportation to the site is not possible or practical. The distance that CWM would be transported by truck would be limited to the lesser of the distance to the closest air transport location or final destination.

Non-stockpile CWM items would be transported in the same container as stored, unless CWM items had been packed in an unapproved shipping container. In this case, the items would be repackaged into approved containers before transporting.

The overpacked non-stockpile CWM items would be monitored with low-level air monitors before loading on the truck to ensure that the items have been properly sealed and are neither contaminated nor leaking.

Up to three escort vehicles each staffed by two military personnel would escort the shipment. Public traffic would not be blocked from the planned route while the transport is being carried out. Military emergency personnel would be placed on standby while the

shipment is in progress, but would not accompany the shipment. In case of an emergency en route, transport personnel would implement first-response activities to mitigate any potential hazard to themselves and the surrounding community while waiting for emergency response personnel to arrive on the scene.

Transport by Military Aircraft. Military helicopters and/or fixed-wing military aircraft would be used to transport CWM items by air. Helicopters would be use if the travel distance were within the safe flight range of the appropriate type of helicopter. Fixed-wing aircraft would be used for longer transport distances. In some instances, a helicopter might be used to transport CWM items to or from a military airfield where the items would be transferred to or from a military fixed-wing aircraft. The only stops that military aircraft would make would be for refueling at military airfields and for layovers if the pilot exceeds the number of safe flying hours prior to reaching the destination airfield.

Trucks would be used to deliver CWM items to the military aircraft from the recovery or storage location and to transport the items from the aircraft-landing site to the treatment system location.

Military escort personnel would accompany the aircraft shipment. Military emergency response personnel would be placed on standby while the air shipment is in progress, but would not accompany the shipment.

The overpacked non-stockpile CWM items would be monitored with low-level air monitors before loading on a transport vehicle to ensure that the items are properly sealed and are not contaminated with agent or leaking. CWM containers would be visually inspected periodically during transport. Appropriate monitoring equipment would accompany the air transport of non-stockpile CWM. Should a situation occur that causes a CWM container to become suspect (for example, exhibits signs of possible leakage), transport could be stopped until contingency and monitoring equipment could be brought to an appropriate site where the transport was halted.

Non-stockpile CWM items would be transported in the same container as stored, unless CWM items had been packed in an unapproved shipping container. In this case, the items would be repackaged into approved containers before transporting.

Transportation Plan. A route-specific transportation plan would be prepared by the NSCMP before transporting CWM to an off-property location. Transportation-related activities that would be addressed in the plan would include packaging, monitoring, mode of transport, routes, emergency response, and a site-specific and route-specific hazard analysis (Department of the Army, 1993a). The plan would be submitted to the U.S. Department of Health and Human Services, and Congress and the Governors of the appropriate states would be notified, as required by federal law (see Section 1.6).

The transportation plan would provide specific instructions to be followed with regard to emergency response should chemical agent or industrial chemicals accidentally be released during transport. The response plan would incorporate an EPZ similar in concept to that for a fixed treatment site (see Section 3.1.3); however, the EPZ for transportation elements would be expanded in area over that of a fixed site as discussed below. The EPZ would establish the area where emergency response concepts would be applied.

As discussed in Section 3.1.3, the EPZ for a treatment site would encompass a circle centered about the potential release point at the treatment site (see Figure 3-2). The radius of the EPZ would be determined by the exposure limit resulting from the maximum credible event (see Section 3.1.1.1).

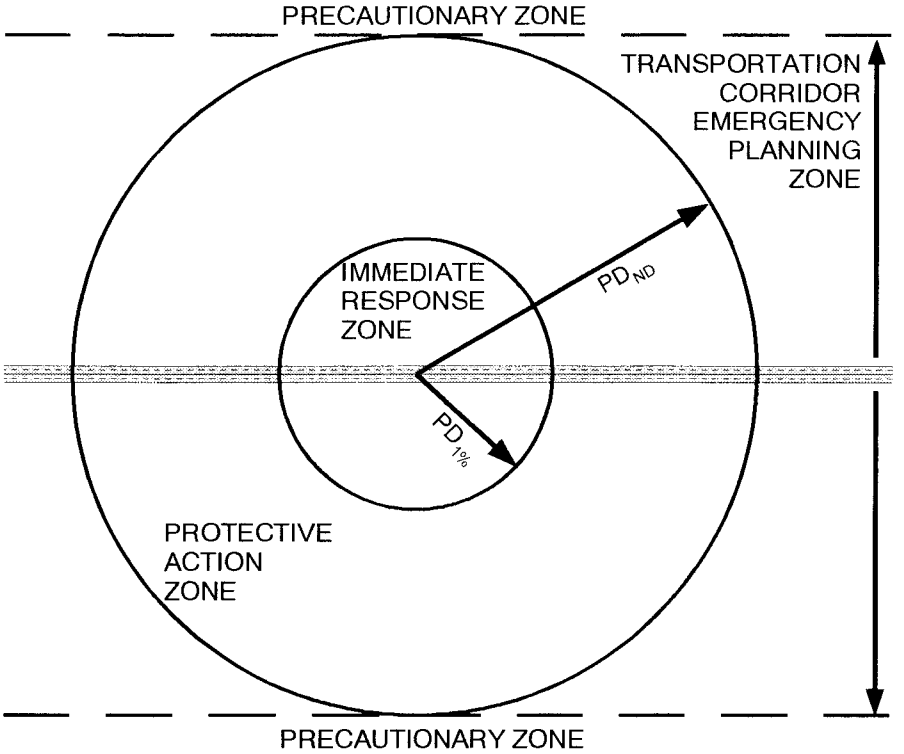
For truck transport, the EPZ area would also be defined as though it was centered about a fixed site—the truck (see Figure 3-3). However, since the truck would move along a road, the EPZ area would also move along the road and would form a corridor centered along the road. In the case of an accidental release, the EPZ area would be centered at the location of the release. An emergency plan would be established for all locations along the route prior to any transport.

For air transport, the fixed-site EPZ concept would be expanded to accommodate the increased risk during takeoff and landing operations (see Figure 3-3). The transportation plan would describe accident-potential zones and clear zones for airport approach and departure that extend to 15,000 feet on either end of all active runways. In order to develop emergency response programs for accidents occurring in these zones, the EPZ for the airfield would be extended in either direction on the assumption that the point source for an accident could be at any point in these zones. The resultant EPZ would be elongated and extend from the storage handling areas, as well as from any point within the extended accident-potential zones on both ends of the runways. The same type of EPZ configuration would be used for any airfields designated as emergency landing sites.

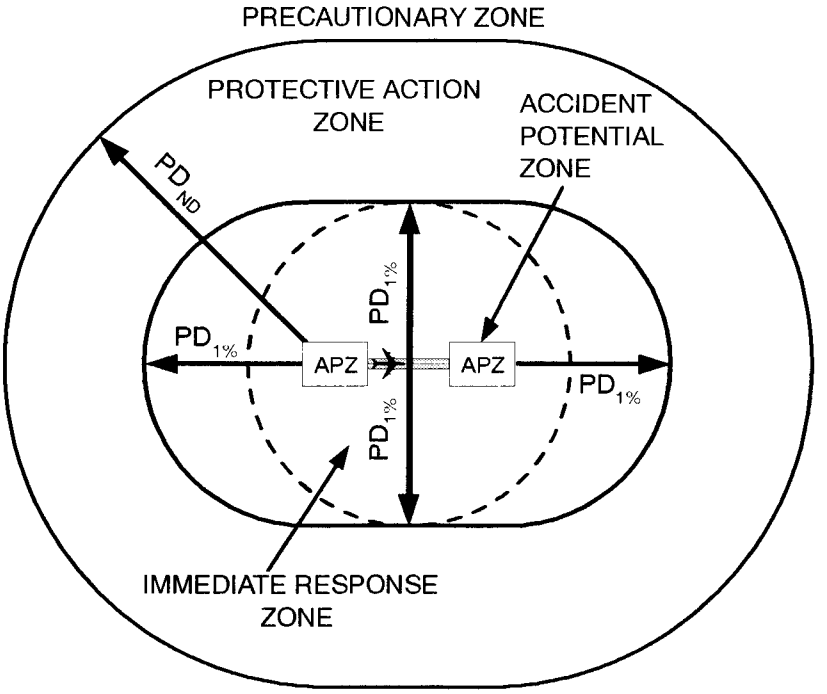
3.1.7 Site Operating Requirements

Operating the transportable treatment systems at a site requires land, utilities, and personnel. The Army must also have various permits and approvals. A number of plans must have been prepared and procedures put in place.

Emergency Planning Zone -- Truck Transport



Emergency Planning Zones -- Air Transport



PD_{ND} - plume distance to no deaths
$PD_{1\%}$ - plume distance to one percent lethality

Figure 3-3. Emergency Planning Zones for Off-Site Transport of Chemical Warfare Materiel

3.1.7.1 Land

Land required to operate the transportable treatment systems at a site is shown below.

Treatment System	Land Area Required
RRS	About 1 acre (0.4 hectares)
MMD-1	1½ acres (0.6 hectares)
MMD-2	3 acres (1.2 hectares)
EDS	Less than 1 acre (0.4 hectares)

3.1.7.2 Utilities

Existing utilities would be used if available at the site. Portable power generators and transportable potable water and wastewater facilities would be used if specific utilities were not available.

3.1.7.3 Personnel

Operating and support staff would be required at a treatment site. Approximate numbers of operating staff for each type of transportable treatment system are as follows:

System	Operating Staff Required
RRS	18
MMD-1	20
MMD-2	40
EDS	Not yet determined

An additional 10-20 people could also be needed for administration, security and other support.

Operating personnel would already be on site, having come for system setup. Operating personnel would be contractor employees that would be assigned to the location without their families for the duration of the project. They would live in motels or apartments rented by the contractor in the local area. If local housing is not available, the contractor would provide temporary housing in mobile quarters moved to the area for this purpose. Workers would commute daily to the treatment site.

Support staff could include administrative, security, food service (if needed), and maintenance personnel. These would likely be local personnel who already live in the region of the site. Food service could be a contracted operation using non-local personnel. On an active military installation, security could be provided by the installation. The system-operating contractor would provide security at a non-military site. The number of support staff required would depend on the infrastructure and operating circumstances at a specific site, but could be of the order of 10-20 people.

3.1.8 Site Operations

Processing and treatment of CWM items would begin after the pre-operational survey is completed and Army approval is given to operate. Processing of CWM items at a treatment location would depend on the items present and the treatment systems used. Descriptions of the treatment operations for the various types of treatment systems are provided in Section 2 and Appendix C. In general, the processing and treatment operations would be as follows:

- Moving CWM items to the treatment system
- Accessing the chemical fill of an item
- Identifying and/or verifying the chemical fill
- Treating chemical agents or, sometimes, phosgene with appropriate treatment reagents and process
- Repackaging industrial chemicals that are not to be treated
- Decontaminating drained munitions and containers
- Treating explosive components in a containment chamber
- Shipping neutralent and other wastes off-site to a TSDF or other appropriate disposal facility

Site operation could last from one or several months to one or two years, depending on the number of items to be treated and processed.

Personnel needed for site operation have been described in Section 3.1.7.

Wastes generated during site operation are described in Section 3.1.10.

3.1.9 Treatment System Closure and Demobilization and Site Closure

The transportable treatment system and site support systems would be decontaminated, demobilized, and removed from the site when treatment of CWM is completed. System decontamination and closure involves cleaning the treatment systems to a state specified in the site RCRA permit or CERCLA Record of Decision that would allow the system to be dismantled and transported safely to the next operating site. Site closure activities could include removing fencing and sediment runoff control devices, removing footings and foundations, and regrading the site as needed. Soil samples would be taken and any contaminated spots would be cleaned up. These activities are described below. Wastes generated during demobilization and site closure are described in Section 3.1.10.

3.1.9.1 Treatment System Decontamination and Cleaning

Treatment equipment that could be contaminated with chemical agent or industrial chemicals would be decontaminated and cleaned to RCRA (or corresponding CERCLA) and Army standards before the treatment systems are decommissioned and moved from the site.

Processes and standards are described below for illustrative purposes. The procedures and requirements described are those required by the state of Utah in the RCRA permits issued for testing of the RRS and MMD-1. Standards for operating at treatment sites would be established in each site permit.

Rapid Response System. The glovebox and associated equipment would be decontaminated using a solution of sodium hypochlorite to destroy organic constituents present on the surface of the material or the pores of the material. All glovebox surfaces and equipment would then be washed with a water spray. The rinse water would be tested and the washing operation repeated until concentrations in the rinsate is 200 ppb or less. Once this performance standard is met, the glovebox would be deemed clean.

Any contaminated areas, structures, or equipment would be wiped manually and then decontaminated using a five percent solution of sodium hypochlorite, detergent solution, or other appropriate decontamination reagent followed by rinsing with water. The rinse water would be tested and the washing operation repeated until concentrations in the rinsate is 200 ppb or less. Once this performance standard is met, the surfaces would be deemed clean.

Filters in the carbon filtration system would be removed from the filter cabinet and containerized for shipment to an approved hazardous waste TSDF.

Before the last carbon filter is removed, the filter cabinet would be decontaminated in the same way as the glovebox. Once the rinsate performance standard is met, the glovebox would be deemed clean.

All wastes generated during closure activities would be containerized, sampled, analyzed, characterized, and managed appropriately based on waste classification and in accordance with applicable regulatory requirements.

Munitions Management Device-Version One. Decontamination would start with the process trailer and progress to the support utility equipment, unpack area, munitions service magazine, and temporary waste storage area. Equipment or contaminated surfaces would be flushed or spray-washed with an appropriate decontamination solution, rinsed with water, and allowed to air dry. The air would be monitored for a four-hour period at or greater than 70°F to detect surface contamination. Rinse water would be sampled for chemical agent. If the results of air monitoring and rinse water analysis are less than Army standards (see Table 3-2), the system would be considered clean. If the standards are not met, the decontamination, rinsing, and monitoring would be repeated until the standards are met. Equipment on skids would be wrapped in plastic in order to conduct the air monitoring.

Filters would be removed after the equipment is determined to be clean. The filters would be bagged in plastic, monitored using MINICAMS® or the depot area air monitoring system, and placed in containers. Filters would be shipped off site for disposal as described in the waste management section.

Table 3-2. Army Closure Standards for Testing of the Munitions Management Device–Version One

Medium	Performance Standard	
Rinse water		
Sarin (GB)	20 ppb	
VX	20 ppb	
Mustard	200 ppb	
Air samples	**mg/m^3**	**ppmv**
Sarin (GB)	0.0001	0.00002
VX	0.00001	0.0000009
Mustard (HD)	0.003	0.00045
Phosgene (CG)	0.4	0.08

After the filters have been removed, the filter cabinets would be monitored. If Army standards are exceeded, the cabinets would be decontaminated and cleaned as described above until standards are attained.

Munitions Management Device-Version Two. Decontamination procedures have not yet been determined for the MMD-2. However, it is likely that they would be similar to procedures and standards described for the MMD-1.

Explosive Destruction System. Specific decontamination procedures have not yet been established for the EDS. These procedures and requirements are expected to be similar to those described for the MMD-1.

3.1.9.2 Site Closure

Once all equipment meets closure standards, the transportable chemical treatment and support systems would be disassembled and removed from the site. The operating crew would be responsible for decontamination, cleaning, and removing equipment and facilities from the site. Subcontractors may help prepare equipment for transportation off the site.

A soil-sampling plan may be implemented to ensure no residual contamination from non-stockpile CWM processing and treatment remains at the site. If contamination is found, soil sampling and other studies would be conducted to determine the amount of environmental contamination that had occurred. The level to which cleanup would take place and the standards to be met would be decided in conjunction with federal, tribal, state, and local regulatory authorities. Ecological and human health risk assessments could be performed to provide data for these decisions. Cleanup standards would be established from various sources, such as those given in Department of the Army (1999d), and standards established by other agencies, such as the USEPA regions.

Any constructed facilities (for example, pads, footings, or structures) would be demolished, if required, and the area returned to a physical state as agreed to during the site identification phase.

Decontamination and site closure could take up to 90 days.

3.1.10 Waste Management

The setup, operation, closure, and demobilization of the transportable treatment systems would generate a variety of wastes at a particular site. Some of these wastes would be a RCRA hazardous waste and some would be a nonhazardous waste. The wastes would be managed (treated, stored, and/or disposed of) in accordance with all applicable laws and regulations.

The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

As discussed below, the facilities used to manage these wastes could include permitted, commercial, RCRA hazardous waste TSDFs; permitted solid waste management facilities (solid waste landfills and municipal solid waste incinerators); wastewater treatment facilities; and recycling facilities. Section 4.6 discusses the waste management regulations that would apply in managing wastes at each of these types of facilities.

The NSCMP has in place a program of auditing and review of TSDFs that treat NSCMP wastes. This program would be applied to TSDFs that accept and treat wastes from the transportable treatment systems. In selecting a specific, permitted, commercial TSDF to receive wastes, the Army would consider the past compliance history of the facility and the type of monitoring and pollution control equipment in use at the facility. The Army would also perform continuing assessments and audits of the performance of all hazardous waste TSDFs selected to ensure that these facilities remain in compliance with all applicable environmental regulations and safety requirements.

3.1.10.1 Wastes from Treatment Site Preparation and Treatment System Setup

Table 3-3 shows the waste streams that would result from treatment site preparation and treatment system setup activities. These waste streams would be essentially the same for each type of treatment system and would be similar to the waste generated by most small- or medium-scale construction activities. The volume and specific composition of each waste stream would depend upon such factors as the size of the area required for treatment system setup and operation; the number of personnel present and the timeframe over which they are present for site preparation and system setup; and site-specific conditions such as whether

Table 3-3. Wastes from Site Preparation and Treatment System Setup

Waste Stream	Process of Generation	Physical State	Location for Waste Management
Construction waste and debris	Site preparation; set up of equipment and treatment system	Solid	Permitted solid waste landfill
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility

necessary infrastructure is present or needs to be installed or modified and whether grading of the site and clearing of vegetation is necessary.

All wastes would be transported to treatment, storage, disposal, and/or recycling locations in accordance with all applicable federal, tribal, state, and local laws and regulations, as well as Army regulations (see Section 4.8).

3.1.10.2 Wastes from Treatment System Site Operation and Pre-Operation Survey

Tables 3-4 through 3-7 list the waste streams that would be generated by the operation (and the pre-operational survey) of each of the four types of treatment systems at a particular site. While many of the same types of waste streams would be generated by each of the four systems, the specific composition of many of these waste streams (e.g., neutralents, repackaged industrial chemicals, spent decontamination solutions) would be dependent upon the specific CWM being treated at the site as well as the site-specific composition of that CWM. Tables 3-8 through 3-12 present information on the composition of neutralents generated from processing various chemical agents and the industrial chemical phosgene in the MMD-1. Table 1-2 in Section 1 identifies industrial chemicals that could be encountered and repackaged.

Table 3-4. Wastes from Operating a Rapid Response System at a Treatment Site[a]

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Neutralents	Chemical treatment (oxidation) of chemical agent in CAIS items	Liquid[b]	Permitted commercial hazardous waste TSDF.
Repackaged industrial chemicals	Repackaging of industrial chemical CAIS components in appropriate shipping containers	Varies[c] (solid/liquid)	Permitted commercial hazardous waste TSDF.
Decontaminated metal containers and packing materials	Decontamination of metal containers and packing materials contaminated by agent	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Non-agent contaminated metal containers and packing materials	Unpacking of CAIS items containing industrial chemicals (spill or leak identified)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Uncontaminated metal containers and packing materials	Unpacking of CAIS items (no spill or leak identified)	Solid	Permitted commercial hazardous waste TSDF; permitted solid waste landfill.
Spent decontamination solutions and rinse waters	Decontamination, cleaning, and rinsing operations (including emergency personnel decontamination station)	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent filter elements from carbon filter system	Change-out and replacement of filter elements from carbon filter system	Solid	Permitted commercial hazardous waste TSDF.
Other spent filter elements	Change-out and replacement of filter elements other than those from carbon filter system	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.

Table 3-4. (Concluded)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Used PPE	Disposable gloves and other personal protective equipment generated from waste handling operations (for example, waste drum change-out, filter change-out)	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Laboratory wastes	Laboratory activities (for example, analysis, calibration, maintenance, and cleaning); spent chemicals and materials	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.
Spent cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
HVAC condensate	Use of HVAC systems	Liquid	Tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in containers for subsequent treatment at an existing wastewater treatment facility.
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Includes wastes from the pre-operational survey.

[b] The neutralent wastes would contain pieces of broken glass. The neutralent waste generated from the treatment of CAIS items containing chemical agent adsorbed onto charcoal would also contain charcoal granules.

[c] The physical state would vary depending on the industrial chemical CAIS items present.

[d] Wastes would be tested for the presence of chemical agent, as appropriate. If present, the waste would be decontaminated and sent to a RCRA hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

CAIS – Chemical agent identification set
HVAC – Heating, ventilating, and air conditioning
PPE – Personal protective equipment
TSDF – Treatment, storage and disposal facility

Table 3-5. Wastes from Operating a Munitions Management Device–Version One at a Treatment Site[a]

Waste Stream	Process of Generation	Physical State	Location for Waste Management[c]
Neutralents	Chemical treatment of chemical agent fills	Liquid[b]	Permitted commercial hazardous waste TSDF.
Neutralents	Chemical treatment of industrial chemical fills	Liquid[c]	Permitted commercial hazardous waste TSDF.
Repackaged industrial chemicals	Draining and transferring industrial chemical fills from munitions or containers to appropriate shipping containers	Varies[d] (solid/liquid)	Permitted commercial hazardous waste TSDF.
Decontaminated overpacks, metal containers, munition casings, and metallic packing materials	Decontamination of chemical agent contaminated overpacks, metal containers, munition casings, and packing materials	Solid (may contain free liquids)	Recycling facility (Rock Island Arsenal or similar DoD facility). Otherwise, permitted commercial hazardous waste TSDF.
Decontaminated non-metallic packing materials	Decontamination of non-metal packing materials contaminated by agent	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Non-agent contaminated metal containers and munition casings	Processing of munition casings and containers with industrial chemical fills (following draining of the fill)	Solid	Recycling facility (Rock Island Arsenal or similar DoD facility). Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated overpacks	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid (may contain free liquids)	Cleaned and reused. Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated packing materials	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Uncontaminated overpacks	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Reuse.
Uncontaminated packing materials	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Permitted solid waste landfill.

Table 3-5. (Continued)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[f]
Spent decontamination solutions and rinse waters	Decontamination, cleaning, and rinsing operations (including emergency personnel decontamination station)	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility
Bead blast residue	Abrasive cleaning and descaling of decontaminated metal munitions bodies and parts from munitions with chemical agent fills	Solid	Permitted commercial hazardous waste TSDF.
Bead blast residue	Abrasive cleaning and descaling of decontaminated metal munitions bodies and parts from munitions with industrial chemical fills	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Spent carbon and other filter elements	Change-out of filter elements and carbon from filtration units associated with the processing of chemical agent (for example, carbon filtration unit and carbon adsorption unit)	Solid	Permitted commercial hazardous waste TSDF.
Other spent filters	Change-out and replacement of filter elements not associated with the processing of chemical agent	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Used PPE[f]	Personal protective equipment generated from treatment system operations	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Laboratory wastes	Laboratory activities (for example, analysis, calibration, maintenance, and cleaning); spent chemicals and materials	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.

Table 3-5. (Concluded)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[e]
Spent cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
HVAC condensate	Use of HVAC systems	Liquid	Tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in containers for subsequent treatment at an existing wastewater treatment facility.
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Includes wastes from the pre-operational survey.

[b] The neutralent waste generated would be dependent upon the chemical agent fills of the chemical munitions to be treated at each site location.

[c] The neutralent waste generated would be dependent upon the industrial chemical fills of the munitions to be treated at each site location.

[d] The physical state would vary depending on the industrial chemical present.

[e] Wastes would be tested for the presence of chemical agent, as appropriate. If present, the waste would be decontaminated and, except for decontaminated overpacks, metal containers, munition casings, and packing materials, would be sent to a permitted commercial hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

[f] Single-use personal protective equipment would be disposed. Multi-use (reusable) personal protective equipment might be cleaned and reused rather than disposed. This would be a site-specific decision based on such factors as practicality, cost-effectiveness, integrity of the item, and availability of laundry facilities.

DoD – Department of Defense
HVAC – Heating, ventilating, and air conditioning
PPE – Personal protective equipment
TSDF – Treatment, storage and disposal facility

Table 3-6. Wastes from Operating a Munitions Management Device–Version Two at a Treatment Site[a]

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Neutralents	Chemical treatment of chemical agent fills	Liquid[b]	Permitted commercial hazardous waste TSDF.
Neutralents	Chemical treatment of phosgene fills	Liquid	Permitted commercial hazardous waste TSDF.
Repackaged industrial chemicals	Draining and transferring industrial chemical fills from munitions and bulk items to appropriate shipping containers	Varies[c] (solid/liquid)	Permitted commercial hazardous waste TSDF.
Decontaminated overpacks, metal containers, munition casings, metal fragments, and metallic packing materials	Decontamination of chemical agent contaminated overpacks, metal containers, munition casings, metal fragments, and packing materials	Solid (may contain free liquids)	Recycling facility (Rock Island Arsenal or similar DoD facility). Otherwise, permitted commercial hazardous waste TSDF.
Decontaminated non-metallic packing materials	Decontamination of non-metal packing materials contaminated by agent	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Non-agent contaminated metal containers and munition casings	Processing of munition casings and containers with industrial chemical fills (following draining of the fill)	Solid	Recycling facility (Rock Island Arsenal or similar DoD facility). Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated overpacks	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid (may contain free liquids)	Cleaned and reused. Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated packing materials	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Uncontaminated overpacks	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Reuse.

Table 3-6. (Continued)

Waste Stream	Process of Generation	Physical State	Location for Waste Managementd
Uncontaminated packing materials	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Permitted solid waste landfill.
Spent decontamination solutions and rinse waters	Decontamination, cleaning, and rinsing operations (including emergency personnel decontamination station)	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Bead blast residue	Abrasive cleaning and descaling of decontaminated metal munitions bodies and parts from munitions with chemical agent fills	Solid	Permitted commercial hazardous waste TSDF.
Bead blast residue	Abrasive cleaning and descaling of decontaminated metal munitions bodies and parts from munitions with industrial chemical fills	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Energetic residues	Intentional detonation of decontaminated munition bodies with intact energetics	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Spent carbon and other filter elements	Change-out of filter elements from filtration units associated with the processing of chemical agent (for example, carbon filter unit system)	Solid	Permitted hazardous waste TSDF.
Other spent filters	Change-out and replacement of filter elements not associated with the processing of chemical agent	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Used PPE[e]	Personal protective equipment generated from treatment system operations	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.

Table 3-6. (Concluded)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Laboratory wastes	Laboratory activities (for example, analysis, calibration, maintenance, and cleaning); spent chemicals and materials	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.
Spent cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
HVAC condensate	Use of HVAC systems	Liquid	Tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in containers for subsequent treatment at an existing wastewater treatment facility.
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Includes wastes from the pre-operational survey.

[b] The neutralent waste generated would be dependent upon the chemical agent fills of the chemical munitions to be treated at each site location.

[c] The physical state would vary depending on the industrial chemical present.

[d] Wastes would be tested for the presence of chemical agent, as appropriate. If present, the waste would be decontaminated and, except for decontaminated overpacks, metal containers, munition casings, etc., would be sent to a permitted commercial hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

[e] Single-use personal protective equipment would be disposed. Multi-use (reusable) personal protective equipment might be cleaned and reused rather than disposed. This would be a site-specific decision based on such factors as practicality, cost-effectiveness, integrity of the item, and availability of laundry facilities.

DoD – Department of Defense

HVAC – Heating, ventilating, and air conditioning

PPE – Personal protective equipment

TSDF – Treatment, storage and disposal facility

Table 3-7. Wastes from Operating an Explosive Destruction System at a Treatment Site[a]

Waste Stream	Process of Generation	Physical State	Location for Waste Management[c]
Neutralents	Chemical treatment of chemical agent fills and explosive residues	Liquid[b]	Permitted commercial hazardous waste TSDF.
Neutralents	Chemical treatment of industrial chemical fills and explosive residues	Liquid[b]	Permitted commercial hazardous waste TSDF.
Decontaminated metal fragments, pieces of munition casing, and fragmentation shields	Decontamination of chemical agent contaminated metal parts in the EDS vessel after detonation and treatment	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Decontaminated overpacks and packing materials	Unpacking of munitions containing chemicals agent fills from overpacks (spill or leak detected)	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Non-agent contaminated metal fragments, pieces of munition casing, and fragmentation shields	Processing of munition casings and containers with industrial chemical fills (following draining of the fill)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated overpacks	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid (may contain free liquids)	Cleaned and reused. Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated packing materials	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Uncontaminated overpacks	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Reuse; otherwise, permitted solid waste landfill.
Uncontaminated packing materials	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Reuse; otherwise, permitted solid waste landfill.

Table 3-7. (Continued)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[c]
Decontaminated non-metallic munition fragments	Decontamination of agent/non-agent chemical munitions in the EDS vessel after detonation and treatment	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Spent decontamination solutions and rinse waters	Decontamination, cleaning, and rinsing operations (including emergency personnel decontamination station)	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent filter elements	Change-out of filter elements from pollution control systems associated with the processing of chemical agent or industrial chemicals	Solid	Permitted commercial hazardous waste TSDF.
Used PPE[d]	Personal protective equipment generated from treatment system operations	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Laboratory wastes	Laboratory activities (for example, analysis, calibration, maintenance, and cleaning); spent chemicals and materials	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.
Spent cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.

Table 3-7. (Concluded)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[c]
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Includes wastes from the pre-operational survey

[b] The neutralent waste generated would be dependent upon the chemical agent fills of the chemical munitions to be treated at each site location.

[c] Wastes would be tested for the presence of chemical agent, as appropriate. If present, the waste would be decontaminated and sent to a permitted commercial hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

[d] Single-use personal protective equipment would be disposed. Multi-use (reusable) personal protective equipment might be cleaned and reused rather than disposed. This would be a site-specific decision based on such factors as practicality, cost-effectiveness, integrity of the item, and availability of laundry facilities.

EDS – Explosive Destruction System

PPE – Personal protective equipment

TSDF – Treatment, storage and disposal facility

Table 3-8. Composition of Neutralent Wastes from the Rapid Response System[a]

Waste Component	Treatment Process		
	Blue (percent by weight)	Red (percent by weight)	Charcoal or Charcoal-L (percent by weight)
Chloroform	54.5–55.5	60–61	50–84
T-butyl alcohol	26–27	17–20	0–24
Water	2.2–2.4	1.7–1.9	0–1
Dichlorodimethylhydantoin (unreacted)(DCDMH)		0–4.6	0–7
Chlorodimethylhydantoin (CDMH)	2.1–5.9	1.9–5.6	2–6
5,5-dimethylhydantoin (DMH)	1–3	0–4.6	0–3
Chlorinated sulfoxides (diethyl and ethylvinyl)	5.4–7.6	0.6–2.1	0–0.4
Chlorobutanes and chlorobutenes	2.4–3.4	1.2–4.6	0–4
Chlorinated sulfones (diethyl and ethylvinyl)	0–0.1	0–0.06	0–0.3
1,1,2-trichloroethane	0–0.015	0–0.23	0–0.025
Tetrachloroethane[b]	0–0.025	0–0.2	0–0.022
Bis-(2-chloroethyl)amine		0–1	0–0.5
Chlorovinylarsonic acid		0–2.6	0–3
Acetaldehyde and chloroacetaldehyde		0–0.5	
Polychlorinated diethyl sulfides and polychlorinated ethylvinyl sulfide			0–2
Dichloroethane[c]			0–0.03
Pentachloroethane			0–0.03
Hexachloroethane[c]			0–0.01
Chloral hydrate			0–0.7
Glass/plastic	2–3	7.5–10	5–8
Charcoal			5–5.2
Additional RCRA TCLP Constituents *Organics*: Carbon tetrachloride; 1,1-dichloroethylene; tetrachloroethylene; trichloroethylene; vinyl chloride *Metals*: Arsenic, barium, cadmium, chromium, lead, mercury, nickel[d], selenium, silver	**Notes**: Expected to be present in waste. Data on concentrations not yet available. Toxic characteristic metals have been assumed to be impurities in chemical agents. All metals may not be present in all wastes. Lewisite contains arsenic. Data on concentrations not yet available.		

[a] RCRA characterization of the neutralent waste stream will be completed using analytical data obtained from bench-scale demonstrations conducted at the Edgewood Chemical and Biological Center (ECBC), Aberdeen Proving Ground, MD.
[b] May be either isomer, 1,1,1,2-tetrachlorethane or 1,1,2,2-tetrachlorethane.
[c] RCRA TCLP constituents.
[d] Not a TCLP constituent. Included because it is listed in Appendix VIII – Hazardous Constituents in 40 CFR 261.

RCRA – Resource Conservation and Recovery Act
TCLP – Toxicity characteristic leaching procedure (40 CFR 261.24).

Source: Deseret Chemical Depot, 1998.

Table 3-9. Composition of Sarin (GB) Neutralent Wastes from Bench-Scale Tests of the Munitions Management Device–Version One[a]

Waste Component	Concentration
GB	ND (<25 ppb)
Major Constituents	**Wt%**
Water	49.4-49.9
Monoethanolamine (MEA)	33.9-40.3
2-hydroxyethylammonium O-isopropyl methylphosphonate salt	0.7-8.5
Monoethanolamine hydrofluoride salt	0.4-4.6
O-isopropyl O'-(2-aminoethyl)methylphosphonate (GB-MEA complex)	0.3-3.0
Minor Constituents (< 1%)	**Wt%**
Diisopropyl methylphosphonate (DIMP)	0.03-0.36 wt %
Tributylamine (TBA)	0.2-0.017 wt %
1,3-diisopropylurea (DIPU)	45-530 ppm
1,3-diisopropylthiourea (DIPTU)	17-200 ppm
2-hydroxyethylammonium methylphosphonate salt	400-800 ppm
Other methylphosphonates	<100 ppm
RCRA TCLP Constituents	
Organics	**mg/l**
Benzene[b]	6.5-6.8
Hexachlorobutadiene[c]	1.0-1.6[f]
2,4-dinitrotoluene[c]	0.2-1.6[f]
Hexachlorobenzene[c]	0.2-1.6[f]
Methyl ethyl ketone (MEK)[d,e]	0.29-0.54[f]
Metals	**ppm**
Arsenic[d]	0.66-0.76
Barium[d]	ND-0.75
Chromium[d]	410-1080
Lead[d]	550-1300
Nickel[e]	410-500

[a] Treatment reagent: water (55 percent), MEA (45 percent)
[b] RCRA toxicity characteristic component concentration greater than TCLP regulatory level.
[c] RCRA toxicity characteristic components. Quantitation limits were above TCLP regulatory limits.
[d] RCRA toxicity characteristic component concentration less than TCLP regulatory limit
[e] Not a TCLP constituent. Included because it is listed in Appendix VIII—Hazardous Constituents in 40 CFR 261.
[f] Source: Dugway Proving Ground, 1998.

ND – Not detected
RCRA – Resource Conservation and Recovery Act
TCLP – Toxicity characteristic leaching procedure (40 CFR 261.24)
Wt % – percent by weight

Table 3-10. Composition of Mustard (HD) Neutralent Wastes from Bench-Scale Tests of the Munitions Management Device–Version One[a]

Waste Component	Concentration
HD	ND (<50 ppb)
Major Constituents	**Wt%**
Monoethanolamine (MEA)	67-89
Water	8.9-9.9
Monoethanolamine hydrochloride	0.9-13.8
N-(2-hydroxyethyl)thiomorpholine (HETM)	0.6-9.1
Bis-[(2-hydroxyethylamino)ethyl] sulfide (HEAES and other organic sulfides)	0.05-1
Minor Constituents (< 1%)	**Wt%**
1,4-dithiane	0.008-0.16
Chlorinated thiophenes	<1[e]
RCRA TCLP Constituents	
Organics	**mg/l**
Tetrachloroethylene[b]	2.2-2.6
Trichloroethylene[b]	1.4-1.6
Vinyl chloride[b]	5.8-6.9
Hexachlorobutadiene	2.0-3.3[e]
2,4-dinitrotoluene	2.0-3.3[e]
Hexachlorobenzene	2.0-3.3[e]
1,1-dichloroethylene[c]	0.13-0.15
Chloroform[c]	0.14-0.2
Methyl ethyl ketone (MEK)[c,d]	0.33-0.37
Metals	**ppm**
Arsenic[c]	0.14-0.23
Chromium[c,d]	0.531-0.62
Nickel[d]	0.13-0.15
Selenium[b]	3.0-3.6

[a] Treatment reagent: water (10 percent), MEA (90 percent)
[b] RCRA toxicity characteristic component concentration greater than TCLP regulatory level.
[c] RCRA toxicity characteristic component concentration less than TCLP regulatory limit
[d] Not a TCLP constituent. Included because it is listed in Appendix VIII—Hazardous Constituents in 40 CFR 261.
[e] Source: Dugway Proving Ground, 1998.

ND – Not detected
RCRA – Resource Conservation and Recovery Act
TCLP – Toxicity characteristic leaching procedure (40 CFR 261.24)
Wt% – percent by weight

Table 3-11. Composition of VX Neutralent Wastes from Bench-Scale Tests of the Munitions Management Device–Version One[a]

Waste Component	Concentration
VX	ND (<1 ppm)
Major Constituents	**Wt%**
Monoethanolamine (MEA)	77.6-83.0
Water	6.9-7.0
Sodium hydroxide	4.2–6.3
Sodium 2-diisopropylaminoethanethiolate (NaThiol)	1.4–0.5
Sodium O-ethylmethylphosphonate (NaEMPA)	0.6-2.0
Sodium O-(2-aminoethyl) methylphosphonate (NaAEMPA)	0.5-1.8
Minor Constituents (<1 %)	**Wt%**
Disodium methylphosphonate (Na_2MPA)	0.15-0.5
Bis-(2-diisopropylaminoethyl)sulfide (Sulfide)	0.22-0.71
Bis-(2-diisopropylaminoethyl)disulfide (Disulfide)	0.13-0.41
2-diisopropylaminoethyl ethyl sulfide	0.03-0.09
1,3-dicyclohexylurea	0.1-0.35
Ethanol	0.2-0.7
Unquantified identified products[b]	0.4-1.0
RCRA TCLP Constituents	
Organics:	**mg/l**
Benzene[c]	1.0-7.5[e]
Carbon tetrachloride[c]	<1.0[e]
1,2-dichloroethane[c]	<1.0[e]
1,1-dichloroethylene[c]	<1.0[e]
Tetrachloroethylene[c]	<1.0[e]
Trichloroethylene[c]	<1.0[e]
Vinyl chloride[c]	<1.0[e]
Metals:	**ppm**
Chromium[d]	0.38-0.44
Lead[d]	1.2-1.4
Selenium	<1.0-4.1

[a] Treatment reagent: MEA (85 percent), water (7.5 percent), sodium hydroxide (7.5 percent)
[b] Compounds identified: cyclohexylamine (CHA); 2-diisopropylamino ethanol (DIPAE); 2-diisopropylamino ethanethiol (VX thiol); 2-(diisopropylamino)ethyl sulfide (DIPAES); chloromethyl-2-(diisopropylamino) ethyl sulfide (DIPAMS); N-2-[(chloromethylthio) methylthio]ethyl-N-isopropyl-2-propanamine; Bis(2- diisopropylaminoethyl)sulfide (VX sulfide); Bis(2- diisopropylaminoethyl) disulfide (VX disulfide); N-2-0[(2-diisopropylamino)ethylthiomethylthio ethyl-N-isopropyle-2-propanamine (VX Me disulfide); Ethylene glycol (EG); N-2-hydroxyethyl methylphosphoramidate (VX-N-MEA)
[c] RCRA toxicity characteristic component concentration greater than TCLP regulatory level.
[d] RCRA toxicity characteristic component concentration less than TCLP regulatory limit.
[e] Source: Dugway Proving Ground, 1998.

ND – Not detected
RCRA – Resource Conservation and Recovery Act
TCLP – Toxicity characteristic leaching procedure (40 CFR 261.24)
Wt % – percent by weight

Table 3-12. Composition of Phosgene Neutralent Wastes from Bench-Scale Tests of the Munitions Management Device–Version One[a]

Waste Component	Percent by Weight
Water	90
Sodium hydroxide (NaOH)	8-9
Sodium carbonate (Na_2CO_3)	1-2
Sodium chloride (NaCl)	1-2

[a] Treatment reagent: water (90 percent), sodium hydroxide (10 percent)
Source: Dugway Proving Ground, 1998.

Table 3-13 shows the number of CWM items estimated to be processed and/or treated daily by each treatment system. With regard to the MMD-1, in current testing it is being operated at the rate of one CWM item per day; however, this rate might eventually be higher. To be conservative, the analysis in this environmental impact statement assumes that the MMD-1 would be operated at a rate of two CWM items per day.

Table 3-13 also shows the amount of neutralent waste estimated to be generated daily by each treatment system. To the extent data are available, the table also indicates estimated quantities of other wastes that could be routinely generated on a daily basis from each treatment system. Some other wastes, such as spent filter elements, spent oils, and spill cleanup materials, would be generated only occasionally; data are not available on the quantity of these wastes that could be generated.

All wastes directly associated with agent would be sent to a permitted, commercial, RCRA hazardous waste TSDF for management, except for certain metallic wastes that would be sent to a DoD smelter as discussed below. The wastes associated with agent would include neutralents and some of the spent filter elements, used personal protective equipment, laboratory waste, spill cleanup materials, and spent decontamination solutions and rinse waters (see Tables 3-4 through 3-7). Decontaminated overpacks, metal containers, munition casings, metal fragments, and metallic packing materials from the MMD-1 and MMD-2 would generally be sent to a DoD smelting facility (such as Rock Island Arsenal, Illinois) for smelting and eventual recycling. In addition, all repackaged industrial chemicals would also be sent to a permitted, commercial hazardous waste TSDF for management. The wastes would all be sampled and analyzed in accordance with RCRA requirements.

The remaining waste streams generated during site operations would also be tested for the presence of chemical agent, as appropriate. Any waste stream identified as having agent present would be decontaminated, analyzed in accordance with RCRA requirements, and then sent to a permitted, commercial hazardous waste TSDF for management. The rest of the waste streams would each be sampled and analyzed in accordance with RCRA requirements to determine if it is a RCRA hazardous waste or a solid (nonhazardous) waste. If it were a hazardous waste, it would be sent to a permitted, commercial hazardous waste TSDF. If not, it

Table 3-13. Estimated Quantity of Waste Generated Daily from Each Treatment System

Treatment System	Estimated Number of CWM Items Processed and Treated Daily	Neutralent Waste Generated (gallons/day)	Other Wastes Generated (pounds/day)
RRS	40–45 CAIS ampoules or 12-15 CAIS bottles [a]	≤15 [b]	c
MMD-1	2 CWM munitions or containers [d]	600	e
MMD-2	2 CWM munitions or containers	600	f
EDS	1 CWM munition or container	330	g

[a] This is the number of CAIS bottles and ampoules treated when CAIS treatment operations are initiated. CAIS ampoules and bottles would first be unpacked from their shipping and storage containers, identified, segregated, and stored until a sufficient quantity were accumulated for treatment. Approximately one container would be processed in this way per day and stored for subsequent treatment. This processing would generate approximately one 30-gallon (114-liter) drum of container and packing material waste per day during such operations.

[b] One gallon or less of neutralent waste is estimated to be generated for every three CAIS (40-milliliter) ampoules or one CAIS (110-milliliter) bottle treated.

[c] Approximately 50 pounds of solid waste and one 100-pound filter element are estimated to be generated per day. Data are not available on the quantities of other wastes that could be generated per day.

[d] In current testing the MMD-1 is being operated at the rate of one CWM item per day; however, this rate might eventually be higher. To be conservative, the analysis in this environmental impact statement assumes that the MMD-1 would be operated at a rate of two CWM items per day.

[e] Approximately 100 pounds of used personal protective equipment and 900 pounds of sludge, sediment, and bead blast residue are estimated to be generated per day. In addition, waste from two munition casings or metal containers could be generated per day and recycled or disposed; two overpacks could also be generated per day and reused, recycled, or disposed (see Table 3-5). Data are not available on the quantities of other wastes that could be generated per day.

[f] Approximately 100 pounds of used personal protective equipment, 400 pounds of solid waste from the unpack area, and 900 pounds of sludge and sediment from the processing area are estimated to be generated per day. In addition, waste from two munition casings or metal containers could be generated per day and recycled or disposed; two overpacks could also be generated per day and reused, recycled, or disposed (see Table 3-6). Data are not available on the quantities of other wastes that could be generated per day.

[g] Data are not available to estimate waste quantities generated per day; quantities would likely be similar to those from an MMD-2.

CAIS – Chemical agent identification sets
CWM – Chemical warfare materiel
EDS – Explosive Destruction System
MMD-1 – Munitions Management Device–Version One
MMD-2 – Munitions Management Device–Version Two
RRS – Rapid Response System

would be sent to a permitted solid waste management facility or a wastewater treatment facility, as appropriate to the waste stream. However, spent oils and lubricants would be sent to appropriate recycling facilities. Metal containers, munition casings, metal fragments, and metallic packing materials from the MMD-1 and MMD-2 would generally be sent to a DoD smelting facility for smelting and eventual recycling. Uncontaminated overpacks would generally be reused, rather than smelted or disposed. Non-agent contaminated overpacks would also generally be cleaned and reused. Some sanitary waste and some liquid waste could be discharged directly to a sanitary sewer system rather than being containerized and transported to a wastewater treatment facility.

All wastes would be transported to treatment, storage, disposal, and/or recycling locations in accordance with all applicable federal, tribal, state, and local laws and regulations, as well as Army regulations (see Section 4.8).

3.1.10.3 Wastes from Treatment System Closure and Demobilization and Site Closure

Table 3-14 shows the wastes that would result from treatment system closure and demobilization and from site closure. Except where noted in the table, the waste streams would be essentially the same for each type of treatment system. However, the specific composition of many of these waste streams (e.g., spent decontamination solutions, spill cleanup material, filter elements) would be dependent upon the specific CWM being treated at the site.

All wastes directly associated with agent would be sent to a permitted, commercial hazardous waste TSDF for management. Such wastes would include some of the cleanup materials, spent filter elements, used personal protective equipment, laboratory waste, and spent decontamination solutions and rinse waters. All these wastes would be sampled and analyzed in accordance with RCRA requirements.

The remaining wastes would be tested for the presence of chemical agent, as appropriate. Any waste stream identified as having agent present would be decontaminated, analyzed in accordance with RCRA requirements, and then sent to a permitted, commercial hazardous waste TSDF for management. The rest of the waste streams would each be sampled and analyzed in accordance with RCRA requirements to determine if it is a RCRA hazardous waste or a solid (nonhazardous) waste. If it were a hazardous waste, it would be sent to a permitted, commercial hazardous waste TSDF. If not, it would be sent to a permitted solid waste landfill or a wastewater treatment facility, as appropriate to the waste stream. However, spent oils, lubricants, and spent chiller/coolant fluids would be sent to appropriate recycling facilities. Trash and sanitary waste would be managed as discussed above under operational activities.

All wastes would be transported to treatment, storage, disposal, and/or recycling locations in accordance with all applicable federal, tribal, state, and local laws and regulations, as well as Army regulations (see Section 4.8).

Table 3-14. Wastes from Treatment System Closure and Demobilization and Site Closure

Waste Stream[a]	Process of Generation	Physical State	Location for Waste Management[c]
Spent decontamination solutions and rinse waters	Decontamination, rinsing, and cleanup of treatment system and other equipment as part of closure operations	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Other decontamination and cleanup materials	Decontamination and cleanup of treatment system and other equipment as part of closure operations	Solid	Permitted commercial hazardous waste TSDF if used to decontaminate or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if not, permitted solid waste landfill.
Used PPE[d]	Personal protective equipment generated from closure and demobilization operations	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Laboratory wastes	Laboratory activities associated with treatment system closure (for example, analyses, decontamination, and cleaning); spent materials and chemicals	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.
Filter elements	Removal of filter elements from filtration units associated with the processing of chemical agent (for example, carbon filter system)	Solid	Permitted commercial hazardous waste TSDF.
Other filters	Removal of filter elements not associated with the processing of chemical agent	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Spill cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.

Table 3-14. (Concluded)

Waste Stream[a]	Process of Generation	Physical State	Location for Waste Management[c]
Debris	Debris from removal of treatment system and other equipment from site and from any site restoration activities	Solid	Permitted commercial hazardous waste TSDF if debris associated with spill or leak of agent. Otherwise, debris tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
HVAC condensate	Use of HVAC systems	Liquid	Tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in containers for subsequent treatment at an existing wastewater treatment facility.
Spent coolant/chiller fluids[b]	Removal of fluid from chiller/heat exchanger at the time of closure of the MMD-1 or MMD-2 onsite	Liquid	Recycling facility.
Spent hydraulic fluid	Removal of fluid at the time of closure of the MMD-1 or MMD-2	Liquid	Recycling facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Applies to all treatment systems except where otherwise noted.

[b] Applies only to MMD-1 and MMD-2. Fluid currently is propylene glycol.

[c] Wastes would be tested for the presence of chemical agent, as appropriate. If present, the waste would be decontaminated and sent to a permitted commercial hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

[d] Single-use personal protective equipment would be disposed. Multi-use (reusable) personal protective equipment might be cleaned and reused rather than disposed. This would be a site-specific decision based on such factors as practicality, cost-effectiveness, integrity of the item, and availability of laundry facilities.

HVAC – Heating, ventilating, and air conditioning
MMD-1 – Munitions Management Device–Version One
MMD-2 – Munitions Management Device–Version Two
PPE – Personal protective equipment
TSDF – Treatment, storage and disposal facility

3.2 No-Action Alternative

If the no-action alternative is selected, the Army would suspend or discontinue developing the transportable chemical treatment systems described in the preferred alternative, and these systems would not be made available for deployment to treat non-stockpile CWM. The Army would continue research and development on other non-stockpile CWM treatment technologies and methods. A number of possible treatment options are described below and in Appendix G. When a suitable treatment technology, process, or method is developed into a transportable or other suitable system, the system would be made available to be deployed to treat recovered non-stockpile CWM.

As a consequence of discontinuing development of the current transportable chemical treatment systems, DoD would continue the current program for handling non-stockpile CWM at burial sites, at recovery locations, and those items currently in storage. Burial sites would continue to be assessed to protect public health and safety and the environment under ongoing military installation or U.S. Army Corps for Engineer programs. CWM currently being stored would continue to be stored, monitored, and maintained. Any non-stockpile CWM recovered from burial sites or test and firing ranges in the future would be placed in long-term storage and monitored and maintained as required. Long-term storage would be at the recovery location if site characteristics allow it. If the items could not be stored at the recovery location they would be transported to a suitable storage location elsewhere. Any recovered non-stockpile CWM that must be stored elsewhere could only be transported to a location in the same state in which the recovered item is located or to the nearest stockpile CWM storage location with the necessary permits to receive and store the non-stockpile CWM (see Section 1.6). Figure 3-4 is a diagram of storage activities under the no-action alternative and other storage activities that are either ongoing or that would be undertaken to facilitate the recovery of non-stockpile CWM from burial sites.

Implementing the no-action alternative would not relieve the United States or the Army of the requirement to destroy stored or recovered non-stockpile CWM in order to protect human health and safety and the environment or to comply with the provisions of the Chemical Weapons Convention. If the Army could not develop a new CWM treatment method in a timely manner under this alternative, it is possible that the United States could not meet the original timelines for destroying CWM established by the Chemical Weapons Convention and may have to request an extension of the deadlines (see Section 1.1 and Appendix H) .

The only Army decision to be made under the no-action alternative is whether to suspend or discontinue development of the transportable treatment systems described in Section 2 and Appendix C and to continue reviewing and assessing other treatment technologies, methods, and processes. The Army is not making any decisions based on this environmental impact statement about burial site remediation, storage site locations or activities, selection of future treatment methods, or deployment of future treatment systems to specific treatment sites.

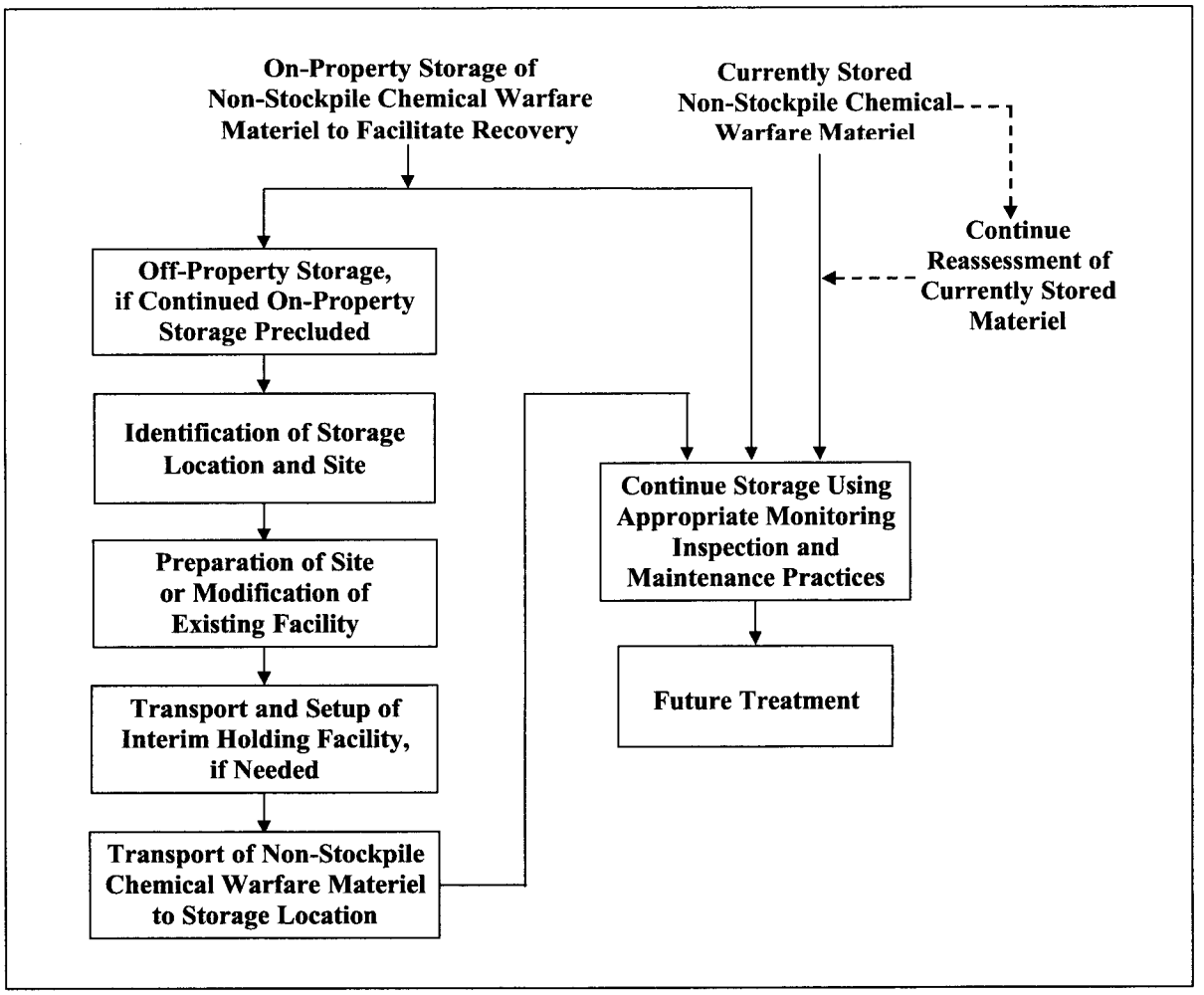


Figure 3-4. Activities Under the No-Action Alternative

Described below are the activities that would take place if the no-action alternative were selected. Any decisions associated with the activities describe below are site-specific decisions. These decisions would be made only after appropriate environmental, safety, and other reviews and analyses are carried out and required public involvement activities are conducted. These activities are described only as the basis for the environmental impact analysis of the no-action alternative presented in Section 7.

3.2.1 Continued Management of Burial Sites

Current environmental management activities at CWM burial sites would continue into the future. Assessment and management of burial sites located on active military installations would continue to be the responsibility of the installation command under the provisions of RCRA or CERCLA, as applicable. Decisions to leave materiel buried or to exhume the materiel would continue to be made by the installation command in consultation with the appropriate federal, tribal, and state regulatory agencies and with public comment and input. Assessment and management of sites on formerly used defense sites no longer under the control of DoD would continue to be the responsibility of the U.S. Army Corps of Engineers. Decisions regarding the removal of CWM would continue to be made by the Corps of Engineers manager and property owner in consultation with the appropriate federal, tribal, and state regulatory agencies and with public comment and input. These activities are described in more detail in Section 3.4.

3.2.2 Continued Storage of Currently Stored Materiel

Current responsibilities for storage, monitoring, and maintenance of currently stored non-stockpile CWM would continue. CWM currently stored and managed by an installation command would continue to be the installation's responsibility.

3.2.3 Storage of Materiel Recovered in the Future

Non-stockpile CWM recovered in the future would have to be placed in long-term storage until a treatment method becomes available. CWM could be recovered in the future for a variety of reasons. These could include the need to remove items from a burial site to protect human health and safety or the environment, clearing of a test or firing range of unexploded ordnance, or accidental discovery such as during construction activities or discovery during troop training exercises. An appropriate storage location would be selected and an adequate storage facility made available.

3.2.3.1 Identification of Storage Location

When a non-stockpile CWM item is recovered from a burial site, firing or test range, or by other accidental discovery, the responsible military installation or U.S. Army Corps of Engineers manager would determine whether the materiel could be stored on the recovery site property or at an off-property location. The process used to make this determination would be

similar to that described in Section 3.1.1 for the preferred alternative. Off-property storage locations that could be considered would be limited as prescribed by current federal law to locations in the state where the CWM is recovered or the nearest chemical stockpile storage site having the necessary storage permits to receive and store the non-stockpile CWM (see Section 1.6). Factors considered for any site location would include (1) the proximity and density of populations surrounding a storage site and how a calculated hazard area, including an explosive safety distance, for a site would affect the population surrounding a candidate storage site; (2) the site environmental conditions that could affect or be affected by storage; (3) the physical requirements and infrastructure needed for storage; and (4) the availability of an existing facility that could be used or modified to store non-stockpile CWM.

A storage plan would be prepared as part of the storage site identification activity. This plan would be based in part on the potential risks of storing non-stockpile CWM items. Factors considered in developing an appropriate plan would include the duration of storage and the types and quantity of non-stockpile CWM items to be stored.

3.2.3.2 Preparation of Storage Site or Modification of Existing Facility for Storage

Once the storage site had been identified, approved, and any required permits issued, either the site would be prepared to for a new structure, such as a portable IHFs, or an existing storage facility at the location would be modified to store non-stockpile CWM. Preparing a site for an IHF could include (1) grading of the site, (2) construction of a pad on which to place and anchor the IHF, and (3) clearing of vegetation and trees as needed for a security zone around the IHF. Other necessary site preparation activities could include (1) extending utilities to the site; (2) installing security fencing and signs; and (3) upgrading access roads, as required, to ensure the safe transport of non-stockpile CWM to the IHF. Section 2.5 gives more details of an IHF and its site.

Necessary modifications to an existing facility, such as an ammunition magazine or igloo, could include sealing drains, modifying ventilators or ventilation systems so that they can be closed, and installing monitoring ports so the interior of the building could be monitored or sampled without personnel entry.

Any required arrangements for emergency personnel, security services, and medical support would be finalized before an IHF is transported and set up at the storage site, or before transporting non-stockpile CWM to the site when an existing facility is to be used for storage.

3.2.3.3 Transport and Setup of Interim Holding Facility

If no acceptable existing storage facility were available, portable IHF(s) could be transported to the storage location and set up at the approved site. A commercial carrier or military vehicles would transport an IHF, depending on availability and cost. An IHF complies with USDOT shipping regulations and size and weight restrictions. Once at the storage site, an IHF would be positioned using a forklift, hoist, or crane. Once in position, the IHF would be secured to the foundation and electrical service and lightening protection

systems installed, if required. Arrangements or provisions would be made for several items needed prior to receiving non-stockpile CWM. These include monitoring equipment, handling equipment (for example, forklift, hand cart, dolly, and flat-bed or pick-up truck), and safety equipment (for example, personal protection equipment, decontamination kits, first-aid supplies, and fire extinguishers). Section 2.5 gives more details of an IHF and its site.

3.2.3.4 Transport of Non-Stockpile Chemical Warfare Materiel to an Off-Property Storage Location

The transport of non-stockpile CWM from the recovery site to an off-property storage location would occur in the same manner as described in Section 3.1.6. Prior to transporting any non-stockpile CWM to an off-property storage location, a route-specific transportation plan would be prepared by the NSCMP for all aspects of the transport. Transportation-related activities that would be addressed in the plan would include packaging, monitoring, mode of transport, routes, emergency response, and a site-specific and route-specific hazard analysis.

3.2.4 Monitoring, Inspection and Maintenance of Stored Materiel

Monitoring, inspection, and maintenance activities would continue for all stored non-stockpile CWM as long as it remains in storage. These activities would be conducted in accordance with site-specific permit conditions and applicable U.S. Occupational Safety and Health Administration and military regulations.

The specific monitoring, inspection, and maintenance activities that would be conducted would be specified in site-specific storage plans or procedures. The specific types of monitoring equipment and the frequency of monitoring would depend in part on the types of chemical fills being stored. Monitoring, using appropriate techniques and instrumentation that would be capable of detecting low levels of chemical fills (for example, MINICAMS ®, and colorimetric tubes), would be performed on overpacked CWM items prior to placement into storage. Before entering a storage facility containing chemical agent, monitoring for chemical agents would be conducted remotely using near real-time monitors. Routine surveillance monitoring of the storage of overpacked non-stockpile CWM items would be conducted as specified at each site-specific location.

The condition of the storage facility and surrounding land would also be inspected to ensure that the storage facility is structurally sound and secure. Appropriate response actions would be determined and implemented immediately upon discovery of an unacceptable situation. For those munitions that are stored as explosive ordnance, regulations regarding safety, monitoring, and maintenance for long-term ammunition storage would be applied.

For suspect non-stockpile CWM items currently in storage, assessment activities would continue to be conducted to verify whether suspect items are actually CWM. These assessment activities would include taking suspect items out of storage, using nondestructive techniques (for example, using a portable isotopic neutron spectroscopy system) to analyze

the items and the Munitions Assessment Review Board to analyze the results from the use of nondestructive techniques (see Section 1.9.3).

3.2.5 Future Treatment of Stored Materiel

If the no-action alternative were implemented, the United States would still have a requirement to destroy stored non-stockpile CWM in the future in order to comply with the Chemical Weapons Convention or if public health and safety or the environment could not continue to be adequately protected at a storage location because of deterioration of stored items. Therefore, the Army would still need to develop transportable or other treatment systems for non-stockpile CWM.

The type of CWM treatment technology, method, or process that the Army might develop in the future is not known at this time. There are a number of technologies, processes, and methods that the Army could pursue. These are summarized in Appendix G. However, since the system that might be developed and deployed in the future is unknown, the activities associated with future non-stockpile CWM treatment systems cannot be described at this time. However, many of the same life-cycle activities described for the preferred alternative would likely occur.

3.3 Alternatives Considered but not Analyzed in Detail

The Army has also considered several other alternatives in addition to the preferred alternative (Section 3.1) and the no-action alternative (Section 3.2). These alternatives are described below and the reasons discussed as to why they have been eliminated from detailed evaluation in this environmental impact statement.

3.3.1 Use of the Transportable Treatment Systems with Conditions

Two alternatives considered were variations of the preferred alternative. One was to deploy the transportable treatment systems as described in the preferred alternative, but to store the neutralent wastes that must be thermally treated until some process other than thermal treatment or incineration could be developed for these wastes. Another was to decide programmatically at this time to restrict the operating location of the treatment systems.

3.3.1.1 Store Neutralent and Other Wastes that Require Thermal Treatment

Some neutralents and other wastes produced from the transportable treatment systems could be subject to the RCRA land disposal restrictions (see Sections 1.7 and 4.6.1.3). Combustion (e.g., incineration) could be the required method of treatment for such wastes. For those cases in which combustion would be the required treatment method, the Army considered the possibility of storing these wastes until some other method of treatment could be developed. This alternative has not been considered further because of restrictions imposed by RCRA and requirements of the Chemical Weapons Convention.

Hazardous waste subject to the RCRA land disposal restrictions is also subject to storage restrictions under 40 CFR 268.50. This standard prohibits storage of any hazardous waste that is restricted from land disposal unless the storage is solely for the purpose of accumulating the quantity of waste necessary to facilitate its proper recovery, treatment, or disposal. If storage is necessary, such storage is limited to a period of one year unless the facility can prove to the permitting authority that additional storage time is necessary solely to accumulate the required quantities to facilitate proper treatment. The storage prohibition does not, however, apply (1) if the waste has first been treated using the applicable 40 CFR 268 treatment standard, which in the case of this alternative would be combustion or (2) if the applicable treatment standard has not yet been specified. Neither of these exemptions would apply under this alternative.

It should be noted that RCRA specifically exempts waste military munitions that are chemical agents or chemical munitions from this storage prohibition (40 CFR 266.205[d][2]). Thus, any recovered CWM item is not subject to the one-year storage limitation.

Provisions of the Chemical Weapons Convention also restrict the ability to store treatment wastes for a long period. To remain in compliance with the Convention, the United States would have to be granted a waiver by the international organization responsible for administering compliance with the Convention, or the storage sites would have to be inspected four times per year by international inspectors under the Convention regime.

The Army cannot be certain that the USEPA would grant an exemption from the requirements of RCRA or that a waiver could be obtained under the Chemical Weapons Convention for long-term storage of treatment wastes. Submitting to inspection four times per year would be possible, but it would be expensive to implement since the United States must pay the costs for the inspection activities. The Army also cannot be certain as to how long it could take to find and develop an alternative to combustion for treating the wastes that would be acceptable to state regulatory agencies and the USEPA under RCRA. Therefore, the Army believes that long-term storage of neutralent and other wastes is not feasible at this time.

3.3.1.2 Restrict the Operating Location of the Treatment Systems

An alternative was considered that would decide programmatically at this time to restrict deployment of the transportable treatment systems only to locations on the military installation or other property where the CWM items are stored or being recovered. This alternative is not considered further because the decision as to where to set up and operate a transportable treatment system for CWM items at a specific location must be decided on site-specific basis and cannot be decided programmatically at this time. To do so requires a site-specific analysis based on conditions at the time stored or buried CWM items are determined to require treatment and processing to protect human health and safety and the environment or to comply with the Chemical Weapons Convention. The Army has determined that no programmatic decision of this kind can be made.

3.3.2 Use Technologies or Facilities Other than the Transportable Treatment Systems

Four alternatives considered involved using some technology or facility to treat non-stockpile CWM other than the transportable chemical treatment systems described in Section 2 and Appendix C. Alternatives considered were (1) to use facilities being used, or proposed to be used, to destroy the national stockpile of chemical weapons; (2) to use some treatment technology other than chemical treatment, such as that to be used to destroy the stockpile of mustard agent in ton containers at the Edgewood Chemical Activity, Maryland, and VX in ton containers at the Newport Chemical Depot, Indiana; (3) to use commercially owned and operated facilities, and (4) to build fixed facilities at each site.

3.3.2.1 Use Stockpile Disposal Facilities

Public Law 99-145 and the Chemical Weapons Convention require the Army to dispose of the national stockpile of unitary chemical agents and munitions. These items are stored at the following locations: Anniston Chemical Activity in Alabama, Pine Bluff Chemical Activity in Arkansas, Pueblo Chemical Depot in Colorado, Newport Chemical Depot in Indiana, Blue Grass Chemical Activity in Kentucky, Edgewood Chemical Activity in Maryland, Umatilla Chemical Depot in Oregon, Deseret Chemical Depot in Utah, and Johnston Island in the Pacific Ocean. Commensurate with the Chemical Weapons Convention, Public Law 99-145, and subsequent public laws, the Army is currently proceeding with or pursuing, contingent upon compliance with applicable requirements and approvals, the following:

- Using onsite incineration to dispose of the stockpile of chemical weapons stored at the Anniston Chemical Activity, Pine Bluff Chemical Activity, Umatilla Chemical Depot, Deseret Chemical Depot, and Johnston Island.
- Using onsite neutralization in pilot plants to test the disposal of the stockpile of mustard agent stored in ton containers at the Edgewood Chemical Activity and the stockpile of the nerve agent VX stored in ton containers at the Newport Chemical Depot.
- Evaluating at least two alternative technologies in place of incineration to destroy the stockpile of assembled chemical weapons.

Each of the stockpile disposal facilities that the Army is currently proceeding with (that is, incineration and the neutralization of bulk quantities of mustard and VX agents) are specific to the large quantities of stockpile materiel stored at each location. Each location has different types and quantities of stockpile CWM (for example, artillery projectiles, rockets, and ton containers), and chemical agents. The stockpile disposal facilities would have equipment specific to the stockpile materiel at each location. For example, at stockpile incineration facilities, the facilities would have equipment to disassemble chemical munitions into components (that is, energetics, chemical agents, and metal parts) and to shear or cut apart rockets that are stored at each location. The planned neutralization facilities at the two stockpile locations with only ton containers of chemical agent would have equipment only for accessing chemical agent in ton containers, decontaminating the ton containers, and

preparing the ton containers for recycling or disposal. In addition, each stockpile disposal facility has or would have equipment, such as monitoring equipment, and permits specific to the chemical agents in the stockpile at each location.

Stockpile disposal facilities that have been, or would be established, could technically treat certain limited types of non-stockpile CWM without modification (for example, a non-stockpile ton container of mustard agent, or repackaged chemical samples). Treatment of other non-stockpile CWM items would likely require modifications to both types of stockpile disposal facilities. For example, items in the stockpile are specifically marked with respect to their chemical agent fill, while the markings on non-stockpile CWM that is recovered from burial sites are often obliterated. Stockpile incineration facilities would, therefore, need to be modified to allow accessing and verification of the chemical fill in each non-stockpile CWM. Non-stockpile CWM may also contain chemical agents (for example, nitrogen mustard) and industrial chemicals dating back to the era of World War I (for example, phosgene and cyanogen chloride) that have not been considered as part of the design of stockpile disposal facilities. Stockpile incineration facilities would, therefore, require modifications to permits and equipment modifications to allow either the treatment or repackaging of chemical agents and industrial chemicals contained in non-stockpile CWM that are not contained in the stockpile at a site. Finally, most recovered non-stockpile munitions are expected to be incapable of being disassembled into their component parts, and recovered non-stockpile munitions may be of different types than those present in the stockpile. Stockpile incineration facilities would, therefore, need to provide for a different method of accessing the chemical fills in non-stockpile CWM.

The program for evaluation of alternative technologies for assembled chemical weapons is currently considering technologies that could have an ability to process and treat a variety of stockpile chemical munitions. Some of the technologies being considered could process and treat a variety of chemical munitions without disassembly into its components prior to treatment. Although the alternative technologies being considered by the Assembled Chemical Weapons Assessment Program may offer greater flexibility, the evaluation of the technologies does not include the potential processing and treatment of non-stockpile CWM. Several years will be required to recommend and evaluate at pilot-plant scale at least two alternatives to the baseline process.

Notwithstanding the potential modifications that would need to be made to both types of stockpile disposal facilities, and the developmental status of technologies being considered as part of the Assembled Chemical Weapons Assessment Program, the Army's present policy based on its interpretation of Public Law 99-145 and its legislative history is that stockpile disposal facilities cannot be used for the treatment of non-stockpile CWM. Additionally, Public Law 99-145 requires that stockpile disposal facilities be "...cleaned, dismantled, and disposed of in accordance with applicable laws and regulations..." when the stockpile facilities are no longer needed for the disposal of the stockpile.

In order to treat non-stockpile CWM in stockpile disposal facilities, Army policy requires the current federal law be modified to explicitly identify that one or more stockpile disposal facilities (1) could be used for non-stockpile materiel and (2) would be cleaned, dismantled, and disposed of when they are no longer needed for the disposal of non-stockpile materiel. This could extend the potential period of operation of stockpile disposal facilities for very small quantities of non-stockpile materiel that could be recovered in the next several decades.

In summary, the Army has considered the alternative of the use of stockpile disposal facilities, but has eliminated the use of stockpile disposal facilities for non-stockpile CWM from detailed consideration in this environmental impact statement because of (1) the uncertainties associated in whether potential changes in federal law would occur, (2) cost-effectiveness (that is, maintaining and operating facilities that were designed to treat large quantities of CWM for use with the small quantities of non-stockpile CWM that could be recovered over the next several decades) and feasibility (that is, the treatment of chemical agents or industrial chemicals not contained in stockpile CWM) of using stockpile disposal facilities for purposes other than that which they have been or would be established, and (3) the potential modifications to stockpile disposal facilities that would be required.

3.3.2.2 Use Other Treatment Systems

The Army's emphasis on developing transportable chemical treatment instead of other types of treatment technologies was based largely on (1) the review and evaluations of alternative technologies for the destruction of the national stockpile by the National Research Council of the National Academy of Sciences, (2) prior experience in using chemical treatment methods for chemical agents, (3) the large number of sites throughout the nation that are likely to have only small quantities of non-stockpile CWM, (4) the characteristics of the non-stockpile CWM that would require treatment, and (5) significant public opposition to the use of incineration. The characteristics of non-stockpile CWM that led the NSCMP to focus on transportable chemical treatment systems included the following:

- Initial inability to ascertain the chemical fills of certain non-stockpile CWM without performing an analysis of each CWM item.
- High potential for encountering a wide and varying diversity of chemical agents and industrial chemicals in non-stockpile CWM at any suspect site or location.
- Inability to readily disassemble non-stockpile CWM munitions into their component parts prior to treatment, including separating the explosive components of munitions from the chemical agents or industrial chemicals.

During the scoping process for the environmental impact statement, a few specific treatment technologies, other than chemical treatment, were suggested as an alternative or option under the strategies. The treatment technologies suggested included some of those that were evaluated under the Army's Alternative Technology and Approaches Program for the stockpile of mustard agent stored in ton containers at the Edgewood Chemical Activity and the stockpile of the nerve agent VX stored in ton containers at the Newport Chemical Depot.

After carefully reviewing these and other treatment technologies, the Army has determined that while several treatment technologies could potentially be used in treating non-stockpile CWM, none of the treatment technologies suggested have currently been sufficiently developed as part of an integrated system for the treatment of non-stockpile CWM. Until further development of other treatment technologies is undertaken regarding their integration into a system for non-stockpile CWM, there are large uncertainties regarding feasibility, impacts, costs, and schedule. These uncertainties preclude the Army at this time from determining whether or not to proceed with investing resources in a system using a different treatment technology and in making such a system available for deployment. Therefore, the Army has eliminated other technologies from detailed evaluation in this environmental impact statement.

Although eliminated from detailed evaluation at this time, a future detailed evaluation would be performed on other technologies that are further developed as part of an integrated system should the Army decide (1) not to proceed with transportable chemical treatment systems (that is, the no action alternative), or (2) to proceed at some point in the future with additional and different types of integrated systems. Appendix G describes different accessing and treatment technologies that could be incorporated into a future integrated system.

3.3.2.3 Use Commercial Treatment Facilities

Several commercially owned and operated treatment facilities have the capability to treat hazardous wastes and chemical compounds. Therefore, the Army has considered the possibility that appropriate commercial facilities could be used to treat and process non-stockpile CWM.

Chemical agents are toxic compounds that were manufactured specifically for use by the military to kill, seriously injure, or incapacitate enemy soldiers through their physiological effects. Chemical agents are militarily unique, that is they are not used in or generated from industrial or commercial processes. Consequently, the Army has a long-standing policy that limits the management of chemical agents to DoD military and civilian personnel. A Major Army Command Commander can make exceptions to this policy if the Commander determines that application of the policy to a specific situation is not in the best interests of the Army.

Notwithstanding Army policy, commercial treatment facilities may require several modifications to process or treat chemical munitions. These could include (1) installing equipment and facilities to access chemical agent in chemical munitions, (2) installing monitoring equipment to detect the possible release of chemical agents, (3) using analytical equipment and approved practices and procedures to determine concentrations of chemical agents in wastes and emissions from the treatment process, (4) modifying treatment facilities to contain accidental or intentional detonation of non-stockpile CWM with explosive components, and (5) obtaining modifications to facility permits. Commercial facilities would also have to be open to inspectors under the provisions of the Chemical Weapons Convention.

Unlike chemical agents contained in chemical munitions, CAIS items were produced for the purpose of training soldiers in identifying chemical agents in the field and were not produced to kill, seriously injure, or incapacitate enemy soldiers through their physiological effects. CAIS items contain small quantities of blistering agents in diluted form, industrial chemicals, and agent simulants and do not contain nerve agents. Congress has directed the Army to assess the policies for handling and disposing of CAIS with the intent of investigating alternatives that could result in reducing the cost of destroying these items. Based on an initial assessment, the NSCMP has determined that (1) there are no known technical limitations that would prevent the effective destruction of CAIS items containing mustard agent and lewisite in commercial treatment and disposal facilities; (2) federal law would need to be clarified in regard to the definition of "lethal chemical agent" to allow the commercial treatment and disposal of CAIS items containing mustard agent and lewisite; and (3) when only a small number of CAIS items are present at a site, using commercial treatment and disposal facilities could be considerably cheaper than deploying and treating a small number of CAIS items with the RRS. However, the use of commercial treatment facilities requires clarification of existing federal law and would not eliminate the need for the Army to develop and provide a capability for treating large quantities of CAIS that could be found or recovered at a site.

In summary, the Army has eliminated commercially owned and operated treatment facilities for the treatment of non-stockpile chemical munitions from detailed evaluation in this PEIS because of (1) the uncertainties associated with whether commercially owned and operated treatment facilities could be modified and obtain permits for the treatment of non-stockpile CWM munitions, (2) the transportation limitations imposed by current federal law, and (3) current Army policy. Although the potential commercial treatment of CAIS items is a possibility, it is contingent on (1) further review by the National Research Council, (2) appropriate changes in federal law and Army policies, and (3) site-specific analyses with respect to costs and potential risks.

3.3.2.4 Build Fixed Facilities at Each Treatment Location

The Army has analyzed the possibility of building fixed treatment facilities at non-stockpile CWM storage, burial, and recovery sites and determined that this is not a feasible alternative. There are currently 168 sites at which non-stockpile CWM is believed to be buried, suspected to be buried, or currently stored. Most of these sites are known to have or are suspected of having only a few or a small number of items. Because of this, the Army has determined that it would not be cost-effective to design and construct fixed processing and treatment facilities at all of these locations.

3.4 Comparison of Environmental Consequences of Alternatives

The environmental consequences of the preferred alternative and the no-action alternative are summarized for comparison in Tables 3-18 and 3-19 (located at the end of this section). The environmental consequences of the preferred alternative are presented in detail in Section 5 (for normal operations) and Section 6 (for accidental release of hazardous

substances). The environmental consequences of the no-action alternative are analyzed in Section 7.

Many of the environmental consequences of deploying and operating the transportable treatment systems would be site-specific and would depend on the particular characteristics of the operating site. In general, there would not likely be significant environmental consequences from normal operation of the treatment systems. The impacts of an accidental release of chemical agent or industrial chemicals would also be site-specific, but could result in short-term environmental and human health impacts.

Under the no-action alternative, many of the environmental consequences would be site-specific, also. In general, there would not likely be significant environmental impacts during the storage phase. The impacts of treating the stored and recovered CWM in the future cannot be determined at this time because the type of treatment that might be used is not known. The impacts of an accidental release of chemical agent or industrial chemicals would also be site-specific, but could result in short-term environmental and human health impacts.

3.4.1 Preferred Alternative

If the preferred alternative is implemented, environmental impacts would be possible from normal operations at a treatment site and the associated transport of CWM items, treatment wastes, and treatment chemicals; and from the accidental release of hazardous substances to the environment.

3.4.1.1 Normal Operations

Normal operation of the transportable treatment systems means that all activities at an operating site would take place as planned and designed within engineering controls and without any accidental releases of hazardous chemicals such as chemical agent or treatment wastes. All associated activities, such as transport of CWM, chemicals, and waste and all treatment and disposal activities at the TSDF that receives the operation wastes, also take place as planned, designed, or within regulatory limits.

Operating at a site would disturb from one to six acres of land, depending on the treatment systems operating at a site. Access to economically important minerals under or near the site could be restricted or eliminated for the duration of site activities. Operation of diesel generators for site emergency or operating power could require an air-quality review and permitting depending on the air quality status of the site. No hazardous air pollutants would be emitted from the operating systems because of the filter systems incorporated into the design of the treatment systems. Ecological impacts would depend on the characteristics of the operating site and surrounding land. There could be some land use or economic impacts if the use of adjacent and nearby property is restricted for safety reasons during the period of operation. Environmental justice issues would be site-specific and would have to be considered in the site-selection process.

3.4.1.2 Accidental Release of Hazardous Substances

Hazardous substances could be released accidentally to the environment during activities at a treatment site or associated transportation operations although the risk of such releases is very small. These substances could include chemical warfare agents and industrial chemicals in the CWM items that would be treated and processed, chemicals used in the treatment process, liquid neutralent wastes produced from treating CWM items, and fuel oil or other petroleum products used at a treatment site or in transportation activities. Hazardous substances could be accidentally released at the treatment site, while transporting CWM items or treatment wastes, or at the TSDF that receives the wastes for final treatment and disposal.

Risk of Accidental Release. An accident risk assessment has been performed for the accidental release of chemical agent, industrial chemicals, and treatment wastes (Tables 3-15 and 3-16; risks for transporting treatment wastes are in the intermediate risk group for all systems). Since no specific sites have been analyzed, the analysis was based on generic assumptions about site activities (called unit operations) that would take place if the treatment systems were deployed. The purpose of the accident risk assessment is to identify potential risks to the general public. Risk is a combination of accident frequency and the consequence of the accident.

In general, the risks associated with accidental releases from most of the unit operations considered fall in the lower to intermediate risk group categories. As to be expected, risk associated with the handling and treatment of CWM items with explosive components are greater than those that do not have explosives. Risk associated with accidental releases from explosive detonations is also influenced by the size of the controlled area (an area restricted from members of the general public). A larger controlled area would be necessary to keep risk the lowest. Risks associated with the transport of CWM items by aircraft are also greater, primarily because a controlled area cannot be predetermined for such accidents.

Risk from accidental release of industrial chemicals and treatment wastes during transport to a commercial facility also falls in the lower to intermediate risk group categories. However, the risk is influenced more by the frequency of the transportation accidents and not by the severity of the release (i.e., health consequence as a result of exposure to chemical constituents).

Effects on the Natural Environment. The downwind natural environment could suffer acute affects if chemical agent or industrial chemicals were released into the air explosively or evaporatively at a treatment site or in a transportation accident. Death or injury to plants and animals could occur in the area of the plume if concentrations are great enough. Such an event would be a one-time occurrence that would affect a small area. The magnitude of the impact would be site-specific, but it is unlikely that a release would greatly affect regional populations of organisms. Long-term impacts from residual chemicals in the environment would be unlikely because of the Army cleanup response to a release, and chemical agents would break down quickly in the environment into other products that would be much less hazardous, would not be persistent, and would not bioaccumulate in the food web. Arsenic in lewisite would be long-lived in the environment unless cleaned up.

Table 3-15. Summary of Risk Group Assignments for Unit Operations for Chemical Agent

Controlled Area for Treatment System (meters)	Unit Operation				
	At Treatment Site			Transport to Treatment Location	
	Interim Storage in Portable Buildings	Transport and Handling[a]	Treatment	Transport and Handling[b]	Air Transport
Site-Type B, CAIS Only (CAIS with Mustard [HD])					
			RRS		
200	❍	❍	❍	❍	❍
1,000	❍	❍	❍	❍	
2,000	❍	❍	❍	❍	
Site-Type C, Non-Explosive Munitions (M70 bombs with Mustard[HD])					
			MMD-1		
200	□	□	□	□	□
1,000	□	□	❍	□	
2,000	❍	□	❍	□	
Site-Type E, Explosive Munitions (155-mm projectiles with Mustard [HD])					
			MMD-2 / EDS		
200	□	□	□ / □	□	
1,000	□	□	❍ / □	□	
2,000	❍	□	❍ / □	□	
Site-Type F, Explosive Munitions (155-mm projectiles with Sarin [GB])					
			MMD-2 / EDS		
200	□	□	□ /	□	
1,000	□	□	□ /	□	
2,000	□	□	□ / □	□	
Site-Type G, Chemical Samples (Ton container with Sarin [GB])					
			MMD-2		
200	□	□	□	□	□
1,000	□	□	□	□	
2,000	□	□	□	□	
Site-Type H, Unsafe Munition (155-mm projectile with Sarin [GB])[c]					
			EDS		
200	NA	NA		NA	NA
1,000	NA	NA		NA	
2,000	NA	NA	□	NA	

— upper risk group □ — intermediate risk group ❍ — lower risk group

[a] Transportation and handling between interim storage facility and treatment system.
[b] Transportation and handling between interim storage facility and military airfield by truck, and between destination military airfield and storage facility.
[c] Analyzed only for the treatment unit operation using the EDS. Munition unsafe to move to an MMD-2.

CAIS — Chemical agent identification set
EDS — Explosive Destruction System
mm — millimeter
MMD-1 — Munitions Management Device–Version One
MMD-2 — Munitions Management Device–Version Two
NA — Not applicable

Table 3-16. Summary of Risk Group Assignments for Unit Operations for Industrial Chemicals

Controlled Area for Treatment System (meters)	Unit Operation				
	At Treatment Site			Transport to Treatment Location	
	Interim Storage in Portable Buildings	Transport and Handling[a]	Treatment	Transport and Handling[b]	Air Transport
Site-Type A, CAIS Repackaged Only (CAIS with Phosgene)					
			RRS		
200	□	❍	❍	□	❍
1,000	❍	❍	❍	□	
2,000	❍	❍	❍	□	
Site Type D, Non-Explosive Munitions (M78 bombs with Phosgene)					
			MMD-2		
200	□	□	□	□	□
1,000	□	❍	□	❍	
2,000	□	❍	□	❍	

– upper risk group □ – intermediate risk group ❍ – lower risk group

[a] Transportation and handling between interim storage facility and treatment system.

[b] Transportation and handling between interim storage facility and military airfield by truck, and between destination military airfield and storage facility.

CAIS – Chemical agent identification set

MMD-2 – Munitions Management Device–Version Two

RRS – Rapid Response System

Spills of treatment chemicals and treatment wastes would be hazardous only at the site of the spill because of low volatility and would not likely expose the natural environment. Chloroform wastes would be volatile, but the maximum quantity that could be spilled would result in a small area of effect.

The threat to aquatic systems from a spill of diesel fuel at a treatment site would be site-specific. Site-selection and site-operating planning would minimize or eliminate the potential for environmental impact. Spills of hydraulic fluids and lubricants would not likely have significant effects because of the small quantity present at a site and the standing operating procedures in place to respond to and clean up these spills.

Effects on Human Health and Safety. Accidental releases of chemical warfare agents have the potential to cause injury and death if the release results in exposure. Airborne chemical warfare agents, and the breakdown products EA 2192, 2 -chlorovinyl arsenous acid, and inorganic arsenic represent the principal acute threats from accidental release. Chemical warfare agents are short-lived substances that are unlikely to represent chronic threats. However, inorganic arsenic, 2-chlorovinyl arsenous acid, and dimethylamine have the

potential to present chronic threats. Generally, the probability of accidental release would be small, and the probability of exposure would therefore also be small. In the event of an accidental release, the probability of exposure would still be small because of the siting of the mobile treatment facility, contingency plans developed by the Army, and other site-specific factors.

3.4.2 No-Action Alternative

If the no-action alternative were selected, environmental impacts would be possible from establishing long-term storage facilities for CWM items and treating these items in the future when a treatment method is available. Impacts could also occur from releasing chemical agent or industrial chemicals to the environment at the storage site or during future treatment. Implementing the no-action alternative would not relieve the Army of the requirement to destroy stored or recovered non-stockpile CWM in order to protect human health and safety and the environment or comply with the provisions of the Chemical Weapons Convention.

3.4.2.1 Normal Operations

Impacts at storage sites would be site-specific. Constructing a new storage building would likely have small to modest impacts associated with site preparation and construction of the storage building. Modifying an existing building for storage would likely have few impacts. There could be land use and economic impacts if restrictions were placed on adjacent and nearby property for safety reasons. These impacts would be less likely if storage is on an existing military installation.

The impacts of treating the CWM in the future cannot be determined at this time because the type of technology or method that could be developed is not known.

3.4.2.2 Accidental Release of Hazardous Substances

Chemical agent or industrial chemicals could be released to the environment at a storage location or during transportation of CWM to a storage location or a future treatment site. A release could occur at a storage or treatment location from a handling accident or an external event, such as an earthquake or a plane crash into the storage building, that breaches the overpacks that protect the stored CWM items. A release during transportation could occur in a truck or aircraft crash.

Risk of Release. The risks to the general public associated with an accidental release of chemical agent or industrial chemicals from storage facilities fall in the lower to intermediate risk group categories (see Table 3-17). Risks are primarily from low-frequency external events (e.g., aircraft crash) that result in large releases. The risk from transporting CWM items by truck and/or aircraft to a storage location or from a storage location to a future treatment site would be the same as for the preferred alternative since the activities involved would be the same. The risk associated with an accidental release from a future treatment system or site cannot be determined at this time because the treatment system and site requirements are not yet known. However, continued and prolonged storage is an additional risk not present in the

Table 3-17. Summary of Risk Group Assignments for Unit Operations for Long-Term Storage

Controlled Area around Storage Area (meters)	Unit Operation			
	Long-Term On-Property Storage[a]	Long-Term Off-Property Storage[b]	Transport and Handling[c]	Air Transport[d]
Site-Type A, CAIS Only (CAIS with Phosgene)				
200	□	○	□	
1,000	○	○	□	○
2,000	○	○	□	
Site-Type B, CAIS Only (CAIS with Mustard [HD])				
200	○	○	○	
1,000	○	○	○	○
2,000	○	○	○	
Site-Type C, Non-Explosive Munitions (M70 bombs with Mustard [HD])				
200	□	○	□	
1,000	□	○	□	□
2,000	○	○	□	
Site Type D, Non-Explosive Munitions (M78 bombs with Phosgene)				
200	□	○	□	
1,000	□	○	○	□
2,000	□	○	○	
Site-Type E, Explosive Munitions (155-mm projectiles with Mustard [HD])				
200	□	○	□	
1,000	□	○	□	
2,000	○	○	□	
Site-Type F, Explosive Munitions (155-mm projectiles with Sarin [GB])				
200	□	○	□	
1,000	□	○	□	
2,000	□	○	□	
Site-Type G, Chemical Samples (Ton container with Sarin [GB])				
200	□	○	□	
1,000	□	○	□	□
2,000	□	○	□	

– upper risk group □ – intermediate risk group ○ – lower risk group

[a] Storage facility is located on the military installation or other property where the items w ere recovered. Storage would be in a portable facility.

[b] Storage facility is not located on the military installation or other property where the items were recovered. Storage would be in an igloo.

[c] Transportation and handling between interim storage facility and military airfield and between destination military airfield and off-property storage facility.

[d] Controlled area designation does not apply to air transport.

CAIS – chemical agent identification set

preferred alternative. Furthermore, as CWM items deteriorate with age, there is also a potential for an increase in the frequency of accidental explosive detonations during handling, transport, and treatment of CWM items with explosive components.

Ecological and Human Health Impacts. The impact of releases of chemical agents and industrial chemicals during storage or transportation to or from a storage site would be similar to those that could occur from an accidental release of these substances in the preferred alternative. The impacts of an accidental release during future treatment cannot be determined at this time because the type of treatment systems and site circumstances are not yet known.

Table 3-18. Comparison of Alternatives for Normal Operations[a]

Preferred Alternative	No Action Alternative
Air Quality	
Air emissions would be generated by various activities associated with the setup, operation, closure and demobilization of transportable treatment systems. The types and quantities of emissions generated would be extremely site-specific. Air emissions generated would include criteria pollutants released by the operation of motor vehicles and equipment involved in site activities and in the transport of personnel, equipment, materials, and wastes. Fugitive dust would be released by vehicles, equipment, and activities that disturb the ground surface. Hazardous air pollutants could also be released by vehicles, equipment, and various construction and maintenance related activities, such as painting and solvent cleaning. The transportable treatment systems have been designed with redundant controls to prevent the release of chemical agents, treatment reagents, neutralent waste components, or other industrial chemicals into the environment during operations. Treatment and unpack systems would be placed in trailers or other environmental enclosures under negative air pressure to ensure that any gases that would be released would only be released from an exhaust stack after passing through redundant carbon filter elements. These filters would be selected to capture specific chemicals that would be treated. Near real-time monitors would be strategically located to ensure that no agent or other chemicals used in the systems would be emitted. Air quality impacts would be extremely site specific and would depend upon such factors as the specific types and quantities of air pollutants emitted by the various activities, existing air quality in the area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts would comply with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented, as necessary, prior to the start of operations. All necessary air quality reviews, permits, and approvals would be obtained both before transportable treatment systems were set up at a specific site and before any operations commenced at the site. The specific reviews, permits, and approvals that would be necessary would also be determined on a site-specific basis. The need for additional controls and mitigating measures would be identified and implemented based on these reviews, permits, and approvals. The use of diesel-powered	Air emissions would be generated by various activities associated with the setup and operation of long-term storage facilities. The types and quantities of emissions generated would be extremely site-specific. Emission quantities would typically be less than those from corresponding treatment system activities. Air emissions generated would include criteria pollutants released by the operation of motor vehicles and equipment involved in site preparation and operational activities and in the transport of personnel, equipment, materials, and wastes. Fugitive dust would be released by vehicles, equipment, and activities that disturb the ground surface. Hazardous air pollutants could also be released by vehicles, equipment, and various construction and maintenance related activities, such as painting and solvent cleaning. Air quality impacts would be extremely site specific and would depend upon such factors as the specific types and quantities of air pollutants emitted by the various activities, existing air quality in the area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts would comply with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented, as necessary, prior to the start of operations. All necessary air quality reviews, permits, and approvals would be obtained before a long-term storage facility was set up and operated at a specific site. The specific reviews, permits, and approvals that would be necessary would be determined on a site-specific basis. The need for additional controls and mitigating measures would be identified and implemented based on these reviews, permits, and approvals. Air emissions and related air quality impacts from future technologies, processes, or methods that would ultimately be used to treat the CWM items in long-term storage under this alternative cannot be determined at this time since these technologies, processes, and methods are not yet known.

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Air Quality (Concluded)	
generators to supply primary power at sites where large numbers of CWM items would need to be processed could trigger the need for air quality reviews and permits at such sites, especially for MMD-2 systems.	
Noise	
No significant adverse impacts due to noise from onsite strategy activities are expected. Noise levels could increase during site preparation, setup, operational, and demobilization activities due to transport trucks and construction equipment; however, noise would be of short duration and would occur during normal work hours. Greatest potential impacts could occur if lack on available power requires continuous operations of electric power generators. Once operations were under way, noise impacts from occasional truck traffic would be minor. Use of helicopters to transport non-stockpile CWM offsite could produce additional noise that would approach a disturbance level	Potential noise impacts during storage site preparation would be comparable to those generated by a small construction site. Noise impacts would occur during normal work hours and would be of limited duration. Also, because the storage sites would usually be located away from inhabited areas for safety reasons, any noise generated at the site would be attenuated by distance. There would be no noise impacts during the period non-stockpile CWM items were stored in the IHF or existing storage facilities.
Geology, Minerals, and Soils	
Site soils would be affected by grading and construction activities required for the treatment facilities and could remain affected for the duration of the treatment campaign. Primary impacts would be soil compaction and changes to soil structure, and the potential increase of soil erosion. Mitigating measures could be implemented to minimize impacts. Areas affected would range from 1 to 6 acres, depending upon the treatment systems deployed. Access to economically important subsurface minerals would be temporarily postponed. Off-site transport of CWM for treatment would not impose any additional impacts.	Soils could be affected by ground-disturbing activities necessary to prepare storage facilities for recovered CWM. Modifying existing buildings or bunkers to store CWM would likely have little or no impact on soils. The extent of impacts on soils would be determined by the characteristics of each specific site and the mitigating measures implemented at each site. The impacts would continue as long as the building remained at the location.

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Groundwater	
It is unlikely that groundwater would be affected by site activities. No wells would be drilled. Impacts to groundwater would be determined on a site-specific basis. Normal leaks of petroleum products from equipment operating at a site would be unlikely to have an impact because the volume released would be small and standing operating procedures would be in place to remove contaminated soils from the site before groundwater could be affected.	It is unlikely that activities at the storage site would have much potential to affect groundwater resources. It is unlikely that wells would be drilled at the site. Normal leaks of petroleum products from equipment operating at a site would be unlikely to have an impact because the volume released would be small and standing operating procedures would be in place to remove contaminated soils from the site before groundwater could be affected.
Ecological Environment	
Effects on the ecological environment would depend on the circumstances of each specific site and the ability to select the location of the site to reduce or eliminate adverse impacts. Areas affected could range from 1 to 6 acres. Off-site transport of CWM for treatment would only impose small additional impacts if new ground transportation facilities or helicopter landing pads were constructed.	Effects on the ecological environment would depend on the circumstances of each specific site and the ability to select the location of the storage site so as to reduce or eliminate adverse impacts.
Terrestrial	
The upland environment could be affected by clearing vegetation for road construction or site preparation. Habitat on the site would be lost or reduced in ecological value while site operations take place. The extent of impact would depend upon prior habitat value and mitigating measures identified and implemented during site operations.	Use of an existing building would likely have only minor effects on the upland environment. If a new building must be erected, the upland environment could be affected by clearing vegetation, grading, and other construction activities. The extent of these impacts would depend on the existing physical status and prior disturbance of the site selected. The impacts from accidental releases of CWM are similar to those described for the proposed action.
Wetlands	
Wetlands could be affected if the site contained wetlands within the operating area or if runoff from the site affected adjacent wetlands. Adverse effects from runoff are likely to be controlled to an acceptable level or eliminated by sediment control management measures that would be required by many states and by all military installations. Sediment runoff during site preparation could affect adjacent wetlands. Adverse effects from runoff would likely be controlled to an acceptable level or eliminated by sediment control management measures that would be required by many states and by all military installations.	It is unlikely that wetlands or floodplains would be significantly affected by storage activities because it is highly unlikely that new storage facilities would be located in these environments. If an existing storage building is used that is located in former wetlands, it is unlikely that any additional impacts would result from modifying the building for storing CWM. Sediment runoff from constructing a new storage site could also affect adjacent wetlands. Adverse effects from runoff would likely be controlled to an acceptable level or eliminated by sediment control management measures that would be required by many states and by all military installations.

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Aquatic	
Storm water runoff from the site into adjacent aquatic environments could contain some additional sediment and contaminants because of soil disturbances during site preparation, such as grading. Mitigating measures such as spill response and runoff control should minimize adverse impacts.	Storm water runoff from the site into adjacent aquatic environments could contain some additional sediment and contaminants because of soil disturbances during site preparation, such as grading. Mitigating measures such as spill response and runoff control should minimize adverse impacts.
Threatened and Endangered Species	
Any possible effects on threatened and endangered species would be a site-specific consideration and would have to be evaluated and analyzed when a specific site is considered as a treatment location. If a site must be used or impacts cannot be avoided, the Army or appropriate DoD authority would work with Federal and/or state authorities to implement appropriate mitigating measures for that particular species and site. Mitigating measures could include habitat protection or improvement at another location or restrictions on operations at the site.	Any possible effects on threatened and endangered species would be a site-specific consideration and would have to be evaluated and analyzed when a specific site is considered as a storage location. Consideration of this issue would be part of the site-selection process. If a site must be used or impacts cannot be avoided, the Army or appropriate DoD authority would work with federal and/or state authorities to implement appropriate mitigating measures for that particular species and site. Mitigating measures could include habitat protection or improvement at another location or restrictions on operations at the site.
Waste Management	
All non-stockpile CWM considered in this environmental impact statement would be managed as a hazardous waste. A transportable treatment system used to treat this CWM would be considered a hazardous waste TSDF and would have to comply with all applicable RCRA requirements. The setup, operation, closure, and demobilization of the transportable treatment systems would generate a variety of wastes at a particular site. Some of the wastes would be RCRA hazardous waste and some would be nonhazardous waste. The wastes generated in the largest quantities would include neutralents; repackaged industrial chemicals; decontaminated metal containers, munition casings, and metal fragments; and spent decontamination solutions and rinse waters. The facilities used to manage these wastes would include permitted, commercial, RCRA hazardous waste TSDFs; permitted solid waste management facilities; wastewater treatment facilities; and recycling facilities, as appropriate to each waste. Neutralents, repackaged industrial chemicals, and any other waste directly associated with chemical agent would be sent to a permitted, commercial, hazardous waste TSDF.	All non-stockpile CWM considered in this environmental impact statement would be managed as a hazardous waste. A facility used to store this CWM would be considered a hazardous waste TSDF and would have to comply with all applicable RCRA requirements. The setup, operation, and closure of a long-term storage facility would generate a variety of wastes at a particular site. Some of these wastes could be RCRA hazardous waste and some would be nonhazardous waste. The wastes generated during storage could include spill cleanup materials and spent decontamination solutions and rinse waters. Data are not available to estimate the quantity of wastes that could be generated annually. The facilities used to manage these wastes could include permitted, commercial, RCRA hazardous waste TSDFs; permitted solid waste management facilities; wastewater treatment facilities; and recycling facilities, as appropriate to each waste. Any waste directly associated with chemical agent, such as spill cleanup materials, would be sent to a permitted, commercial, hazardous waste TSDF.

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Waste Management (Concluded)	
The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process. The wastes would be managed in accordance with all applicable federal, state, and local laws and regulations. In selecting specific, permitted, commercial hazardous waste TSDFs to manage the hazardous waste generated, the Army would consider such factors as the operating and compliance history of the facility and the type of monitoring and pollution control equipment present at the facility. In addition, the Army would perform continuing assessments and audits of all hazardous waste TSDFs selected to ensure that these facilities maintain compliance with all applicable environmental and safety requirements. Under RCRA land disposal restrictions, some of the waste sent to a commercial hazardous waste TSDF, such as neutralents and repackaged industrial chemicals, would require treatment before it could be disposed while some could be disposed of in a hazardous waste landfill without any further treatment. Treatment methods that could be used for various wastes include combustion, wet air oxidation, chemical or electrolytic oxidation, carbon adsorption, and deactivation. The specific treatment method used would be determined on a site-specific and waste-specific basis and would depend on the specific composition of the waste stream being managed. The volume of waste generated annually would depend upon such factors as the number and types of treatment systems deployed and the type and quantity of CWM treated by each deployed system. On a national basis, the quantity of hazardous waste estimated to be generated annually would represent a small to insignificant increase in the quantity of waste managed annually at commercial hazardous waste TSDFs. The quantity of nonhazardous waste estimated to be generated annually would represent an insignificant increase in the quantity of such waste managed annually by nonhazardous waste disposal facilities and recycling facilities. Impacts to local waste management facility capacities would be site-specific and would have to be addressed in the site-specific environmental reviews that would be prepared for each site.	The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Utilities	
Water Supply	
Up to 7,500 gals/day of potable water could be needed for a large-scale deployment The impact of the increased water demand on an installations or local water utility would be site-specific and depend on the number of systems deployed and the capacity of the local system. At large military installations and urban sites served by water utilities with excess capacity, the impact would likely be small. At smaller military installations, sites served by water utilities with little or no excess capacity, and sites in arid regions the increased demand could cause adverse impacts on the utility and other water supply users including loss of line pressure, increased sediment entrainment due to higher flows, and increased depletion of local water sources.	Impacts to local or regional utilities would be relatively minor. Relatively small amounts of electrical power would be needed to operate storage facility (igloo or IHF) lighting, monitoring systems, and security systems. Water supply and sanitary waste disposal would be needed in the short term for the personnel needed to prepare the site and storage facilities and in the long term for the few personnel needed to provide security and monitoring at the site.
Wastewater Disposal	
Between about 2,000 and 7,500 gals/day of non-hazardous wastewater could be generated by a large-scale deployment requiring disposal. Impacts would be site-specific and depend on the number of systems deployed and the capacity of the local system. At large military installations and urban sites served by wastewater treatment facilities with excess capacity, the impact would likely be small. However, local impacts could occur if local sewer lines did not have the capacity to handle the flow. At smaller military installations and sites served by wastewater systems with little or no excess capacity, the increased demand could cause adverse impacts on the utility and other sewer system users.	
Electric Utilities	
Up to 1,880 kW of continuous electrical power could be needed for a large-scale deployment. Where local power would be used, the impact on the utility and its users would be site-specific and depend on the number of systems deployed and the capacity of the local power system. At large military installations and urban sites served by an electric utility and line infrastructure with sufficient capacity, the impact would likely be small. At sites served by small electric utilities or lower capacity transmission infrastructures, the impacts on the utility and other users could be significant and include line voltage drops, degradation of line power quality, and system failures.	

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Traffic and Transportation	
Adverse impacts to transportation resources surrounding locations with non-stockpile CWM are likely to be minor and temporary. Potential impacts to traffic and transportation due to site preparation, setup, normal operations, demobilization, and closure activities could include increases in truck and automobile traffic on public roads and highways near the treatment site, increased congestion, noise, increased risk of traffic accidents. If new access roads or modifications to existing roads were necessary to bring in the transportable chemical treatment and support systems or to facilitate movement of non-stockpile CWM from a discovery site to the treatment site, traffic disruption could occur. Transporting non-stockpile CWM to an off-site treatment location would likely have minor impacts on existing roads and highways. Impacts could include increases in traffic and increased risk of transportation accidents involving releases of CWM. It is not likely that the increase in traffic would cause major changes in local traffic patterns.	Potential traffic and transportation impacts would result primarily from the site preparation and setup activities and from transfer of non-stockpile CWM from the discovery site to the storage site.
Cultural Resources	
Cultural and historical resources, archeological sites, and Native American lands and religious areas could either be directly or indirectly affected by on-site and off-site activities, including ground excavation, noise and vibration, access restrictions, evacuation requirements, visual impairments, air emissions, and accidental releases of CWM. Impacts could include (1) potential disturbance or destruction of cultural, historic, or archeological sites, structures, or resources, (2) potential disruption or destruction of Native American religious areas, sacred sites, rituals, and traditional hunting or fishing grounds, and (3) disturbance of previously unknown Native American gravesites. Impacts related to the transport of non-stockpile CWM from the discovery site to an off-site treatment location could be caused by noise, vibration, and air emissions from transport trucks and military aircraft moving non-stockpile CWM items to an off-site treatment location. The extent of such impacts would be site-specific and would depend on the proximity of culturally important resources or lands to the transport routes, the sensitivity of the resources to transport-related impacts, and the amount of non-stockpile CWM to be moved.	At sites where no existing storage facilities are available, site preparation would require trees and vegetation to be cleared in order to establish a clear zone for the deployment of an IHF. The potential for adverse impacts to historic and culturally significant resources and lands of importance to Native Americans could result from (1) long-term conversion of land use, (2) physical disturbance of land, (3) noise generated during site preparation activities, and (4) the potential for accidental releases of non-stockpile CWM.

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Land Use	
The transportable chemical treatment and support systems could require between 1 and 5.5 acres of land, depending on the number of systems deployed and additional land areas that could be affected if other improvements are required (for example, access road and utilities). Land use impacts could include (1) potential conflicts with existing adjacent land uses, (2) conflicts with sensitive land uses, (3) delays in new uses of underlying or nearby lands, and (4) impacts on private lands. Potential for adverse land use impacts could occur if establishment of controlled areas exceed site or property boundaries and planned evacuations are required. Evacuations would be occur during daylight working hours. Transport of non-stockpile CWM to an off-site treatment location could create land use conflicts including use of addition land to construct helicopter land areas, noise from the landing and takeoff of helicopters that would be used in transporting non-stockpile CWM, and impacts to land uses along the transport route, including potential evacuations along the transport route in the event of an accident.	In most cases, deployment of an IHF or use of existing storage magazines or igloos at large, active military installations would not conflict with existing land uses on the installations. At small military installations, properties not under government control, and, possibly, at inactive military installations, deployment of an IHF and long-term storage of non-stockpile CWM could conflict with existing or surrounding land uses. Storage of non-stockpile CWM would preclude other uses of the land until such time as the CWM items were processed or moved to an off-site treatment location. In addition, depending on the need for and size of controlled areas established as a result of evaluating potential accidents, the potential exists that arrangements would have to be made to use private or non-military property or to restrict uses and activities on adjacent private or non-military property.
Socioeconomic Characteristics	
Between 18 and 98 non-local workers could be required to setup, operate, and demobilize the transportable chemical treatment and support systems. Potential socioeconomic impacts could result from increased needs placed on existing community infrastructures and services by in-migrating workers (for example, increased need for housing) and increased demands placed on the use of emergency, hospital, and medical facilities and personnel. If adequate housing is not available, the operations contractor will provide temporary housing for on-site personnel. Establishment of controlled areas could require temporary evacuations of populations if controlled areas exceed site or property boundaries. Evacuations could cause significant direct and indirect socioeconomic impacts depending on the areas affected and the length of time of any required evacuations. The types and levels of socioeconomic impacts that could be caused by non-stockpile CWM activities would be site-specific and would vary based on (1) the local demographic and geographic setting of the sites where activities would occur; (2) the number of systems deployed to a site, and (3) the duration of activities.	Potential socioeconomic impacts could result from needs placed on existing community infrastructures and services by in-migrating workers and by disruptions and evacuations that could be caused by non-stockpile CWM handling and storage. Under the no-action alternative, the community impacts due to in-migrating personnel would be very small. Local contractors and labor would probably conduct site preparation and IHF setup. The greatest in-migration of personnel would occur to accomplish the recovery and transfer of non-stockpile CWM from the discovery site to the IHF or existing storage facilities. These personnel would come without families and if housing were not available, the contractor would provide temporary mobile living quarters. The number would probably be less than 20. Because the recovery and transfer operations would be of limited duration, it is likely that the presence of these personnel would have a small and short-lived impact on the surrounding community.

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Public Health and Safety	
Under normal operations, the setup, operation, closure, and demobilization of the transportable treatment systems would not be expected to pose any significant threat to public health and safety. However, truck and automobile traffic would temporarily increase on roads in the vicinity of the treatment site and could possibly result in a small increase in the number of traffic accidents on such roads. Activities that disturb the ground surface would generate fugitive dust emissions that could drift offsite. Appropriate dust suppression measures would be carried out to minimize the potential public health consequences from the release of fugitive dust. Site-specific impacts and the need for any site-specific mitigating measures would have to be evaluated and analyzed when a specific site is considered as a treatment location. Emergency response plans, including a site emergency response plan and a transportation emergency response plan, would be prepared and implemented before any items containing chemical agent or industrial chemicals were handled, treated, or processed at a specific site. Children would be unlikely to be exposed to disproportionate health or safety risks from treatment system. This would need to be verified in the site-specific environmental reviews that would be prepared for each site.	Under normal operations, the setup, operation, closure, and demobilization of the storage facility would not be expected to pose any significant threat to public health and safety. However, truck and automobile traffic could increase on roads in the vicinity of the storage site and could possibly result in a small increase in the number of traffic accidents on such roads. Activities that disturb the ground surface would generate fugitive dust emissions that could drift offsite. Appropriate dust suppression measures would be carried out to minimize the potential public health consequences from the release of fugitive dust. Site-specific impacts and the need for any site-specific mitigating measures would have to be evaluated and analyzed when a specific site is considered as a storage location. Emergency response plans, including a site emergency response plan and a transportation emergency response plan, would be prepared and implemented before any items containing chemical agent or industrial chemicals were transported to the storage facility or stored in the facility. Children would be unlikely to be exposed to disproportionate health or safety risks from storage activities. This would have to be evaluated and analyzed when a specific site is considered as a storage location.
Environmental Justice	
A potential for disproportionate impacts to minority and low-income populations could occur in site selection and in choices made related to the conduct of treatment operations themselves. Potential impacts could include (1) lost economic opportunity, as new developments choose not to locate in areas in which non-stockpile CWM treatment and processing operations occur; (2) lower property values; (3) potential evacuation impacts; and (4) an increase in the potential for human health and safety impacts. In addition, recovery, storage, or treatment activities would preclude other uses of the land for the duration of the site preparation, treatment operations, and site closure. This could prevent beneficial redevelopment of the treatment site location, especially at closed military bases and other properties.	A potential for disproportionate impacts to minority and low-income populations could occur in site selection for temporary storage facilities. Potential impacts could include (1) lost economic opportunity, as new developments choose not to locate in areas in which non-stockpile CWM is stored; (2) lower property values; (3) potential evacuation impacts; and (4) an increase in the potential for human health and safety impacts. In addition, recovery and storage activities would preclude other uses of the land until the CWM items were processed or moved to an off-site treatment location. This could prevent beneficial redevelopment of the treatment site location, especially at closed military bases and other properties.

Table 3-18. (Continued)

Preferred Alternative	No Action Alternative
Environmental Justice (Concluded)	
The potential for disproportionate environmental impacts to minority or low-income communities would depend on the location of the treatment sites and the presence and proximity of minority or low-income communities to these sites.	The potential for disproportionate environmental impacts to minority or low-income communities would depend on the location of the storage sites and the presence and proximity of minority or low-income communities to these sites.
Cumulative Impacts	
Various other ongoing or future planned actions could occur in the vicinity of any site used to treat CWM in a transportable treatment system and/or any site used to manage wastes generated from the transportable treatment system. The cumulative impacts at any site from the transportable treatment systems and these other actions would be very site-specific and would depend on the nature, location, and number of such other actions. These cumulative impacts would have to be evaluated and analyzed when a specific site is considered as a treatment location. The only cumulative impact that can be quantified on a national basis relates to the volume of waste generated from the transportable treatment systems. This impact is discussed above under waste management.	The cumulative impacts from the long-term storage of non-stockpile CWM would include the impacts from the storage itself, plus the impacts from the ultimate treatment of the CWM being stored, plus the impacts from various other ongoing or future planned actions that could occur in the vicinity of any site used for long-term storage of CWM, any site used in ultimately treating the stored CWM, and/or any site used to manage wastes generated from the storage and ultimate treatment of the CWM. These impacts would all be very site specific. Furthermore, the treatment technologies that would ultimately be used are not known at this time, and consequently their impacts cannot be analyzed at this time. As a result, the cumulative impacts of long-term storage of the CWM cannot be meaningfully analyzed at this time.

[a]Normal operation means that all activities and operations take place as designed planned and within regulatory limits.

CWM – Chemical warfare materiel
IHF – Interim holding facility
HAP – Hazardous air pollutant
MMD-2 – Munitions Management Device, Version 2
RCRA – Resource Conservation and Recovery Act
TSDF – Treatment, storage, and disposal facility

Table 3-19. Comparison of Alternatives if Hazardous Substances are Accidentally Released

Preferred Alternative	No Action Alternative
Risk Associated with Accidental Release	
In general, the accidental release of chemical agent and industrial chemicals contained in CWM items during handling, transport, or treatment could cause adverse health impacts, including injury and death, mainly within the controlled areas where no members of the general public would be expected to be present. Therefore, risks for such operations, in particular for CWM items without explosive components, fall in the lower to intermediate risk group categories. However, the treatment of CWM items with explosive components, as well as the transport of CWM items by aircraft poses greater risk. Accidental release of industrial chemicals and treatment wastes during transport to a commercial treatment facility could lead to adverse health impacts as a result of exposure to volatile chemical compounds. However, the severity of such release is much less than that associated with chemical agent release from accidents during handling, transport, and treatment of CWM items.	Risks associated with continued storage of recovered CWM items fall in the lower to intermediate risk group categories. However, because the CWM items would eventually be treated and destroyed at some time in the future, risk from continued and prolonged storage is an additional risk not present in the preferred alternative. As CWM items deteriorate with age, there is also a potential for an increase in the frequency of accidental explosive detonations during handling, transport, and treatment of CWM items with explosive components. Risks associated with transporting CWM to and from a storage location would be the same as the preferred alternative. Risks associated with future treatment of stored items cannot be determined because the treatment and processing methods are not yet known.
Ecological Environment	
Accidental releases of agents or industrial chemicals through spills or explosive releases could lead to adverse immediate and acute impacts, including injury and death, in the immediate area of the release. Except for highly volatile agents or explosive releases, most spills of agents, reagents, and treatment wastes would have little impact beyond the immediate area of a spill, unless sufficient concentrations are transported downwind through dispersion of aerosols or gases. Long-term impacts are unlikely because releases of most agents or wastes would be contained onsite, the agents are relatively non-persistent, and cleanup plans would be enacted to further reduce the threat. Explosive or volatile releases would also not create a long-term threat because of the rate of degradation of agents and wastes and because of the cleanup that would be undertaken upon release. Arsenic would be long-lived in the environment unless cleaned up. Regardless of the location or type of accidental release, contingency plans would be implemented to clean up any resulting contamination.	Accidental releases of agents or industrial chemicals through spills or explosive releases could lead to adverse impacts, including injury and death, in the immediate area of the release or downwind if sufficient concentrations are transported through dispersion of aerosols or gases. The probability of an accidental release is less than for the proposed action because of the reduced need to handle CWM. Long-term impacts are unlikely, as releases of most agents would either be contained on-site until cleanup, or would be constrained by the containment afforded by the storage facility. Explosive or volatile releases that penetrate the storage facility would have impacts similar to those described for the proposed action and would be unlikely to create any long-term impacts. Arsenic would be long-lived in the environment unless cleaned up. Regardless of the location or type of accidental release, contingency plans would be implemented to clean up any resulting contamination.

Table 3-19. (Concluded)

Preferred Alternative	No Action Alternative
Ecological Environment (Concluded)	
Spills of petroleum products would be unlikely to have an impact because the volume that could be spilled would be small and standing operating procedures would be in place to contain any spill and remove contaminated soils from the site before groundwater or surface waters could be affected.	Spills of petroleum products would be unlikely to have an impact because the volume that could be spilled would be small and standing operating procedures would be in place to contain any spill and remove contaminated soils from the site before groundwater or surface water could be affected
Human Health Effects	
Accidental releases of chemical warfare agents have the potential to cause injury and death if the release results in exposure. Airborne chemical warfare agents and the agent breakdown products EA 2192, 2-chlorovinyl arsenous acid, and inorganic arsenic represent the principal acute threats from accidental release. Chemical warfare agents are short-lived substances that are unlikely to represent chronic threats. However, the breakdown products inorganic arsenic, 2-chlorovinyl arsenous acid, and EA 2192 have the potential to present chronic threats. Accidental releases of industrial chemicals, treatment chemicals, and neutralent waste chemicals have the potential to cause injury primarily through their irritant and/or incapacitating properties, although some can be lethal at high concentrations. The likelihood of exposure to the volatile chemicals—such as phosgene, chloroform, and t-butyl alcohol—would be higher than for the other chemicals. However, these chemicals are generally not persistent in air, and any exposure that might occur would be limited by their rapid dissipation and environmental degradation to form relatively innocuous breakdown products at most sites. Generally, the probability of accidental release would be small, and the probability of exposure would therefore also be small. In the event of an accidental release, the probability of exposure would still be small because of the planning and review involved in siting of the mobile treatment facility, contingency plans developed by the Army, and other site-specific factors.	Accidental releases of chemical warfare agents have the potential to cause injury and death if the release results in exposure. The substances identified as presenting the principal acute and chronic threats under the proposed action would also present the principal threats under the no-action alternative. In the event of an accidental release, the probability of exposure would still generally be small because of the siting of the storage facility, contingency plans developed by the Army, and other site-specific factors.

CWM – Chemical warfare materiel

Section 4

Affected Environment

This section is concerned with the elements of the physical and biological environment and the socioeconomic characteristics that could be affected by operation of transportable treatment systems at a site, by transport of non-stockpile CWM to a distant treatment location, or by the activities of the no-action alternative. The descriptions are not specific to any particular site or location because no site-specific deployment decisions are to be made at this time. The focus is on the characteristics of the environment that could be affected by the preferred alternative and the no-action alternative and on the laws and regulations that govern activities, such as operating CWM treatment systems at a site, that could affect elements of the environment and socioeconomic characteristics of an area.

The discussion of laws and regulations below is only illustrative of the legislative and regulatory environment within which deploying and operating transportable treatment systems would take place. This section is not a complete listing of applicable laws and regulations that would apply to operations at a specific site. All applicable laws and regulations would be determined at the time in the future when a site-specific deployment decision would be made.

Sections 5 and 6 describe how the environmental elements or socioeconomic characteristics could be generally affected if the preferred alternative is implemented. Section 5 describes the possible consequences of normal operations of treatment systems at a site. Section 6 describes the possible consequences if hazardous substances are accidentally released to the environment during treatment system operations at a site or during transport of CWM items to a distant treatment location. Section 7 describes the possible general environmental and socioeconomic consequences if the no-action alternative is implemented.

4.1 Air Quality

Air emissions, usually in minor amounts, would be released by various activities associated with the setup, operation, closure, and demobilization of the transportable treatment systems, including ancillary activities such as waste treatment and disposal. The primary statute regulating air emissions is the Clean Air Act of 1970 (Public Law 91-604), as amended; the major amendment has been the Clean Air Act Amendments of 1990.

The Clean Air Act is a complex body of legislation that is implemented through interrelated federal, state, and local programs and regulations. USEPA has been given the authority to establish air quality standards and other programs to protect public health and the environment by limiting air pollutant emissions from stationary and mobile sources. Stationary sources are air emission sources that stay in one place, such as a power plant or an industrial facility. Mobile sources are air emission sources that move around, such as a car, truck, or

construction equipment. A transportable treatment system, including any generators used for power supply, would be considered a stationary source when used at a treatment site.

The federal role under the Clean Air Act relates primarily to (1) developing national standards and guidelines for the control and abatement of air pollution, (2) ensuring that state programs meet minimum requirements, and (3) providing oversight of state programs. The actual implementation and enforcement of standards and other control mechanisms, including the issuance of air permits, is typically carried out at the state and local level. The federally mandated portions of a state's air program are implemented through State Implementation Plans (SIPs) that must be approved by USEPA. The SIP addresses such parameters as the state's control strategy and its measures, rules, and regulations for ensuring the timely attainment and maintenance of the national standards being implemented. The state may, in turn, delegate permitting and rulemaking authority to regional or local agencies. Some federally mandated requirements may also be delegated by USEPA to Indian Tribes.

The following discussion provides an overview of Clean Air Act requirements applicable to the transportable treatment system life-cycle activities. Ambient air quality standards are discussed first, followed by an overview of requirements for preconstruction permits and approvals, operating permits, accidental release prevention, and air regulations related to the treatment/disposal of transportable treatment system wastes. Some of the requirements apply only if a source can emit a regulated air pollutant in a quantity exceeding a specified regulatory threshold; such a source is called a major source. The specific air pollutants and thresholds used to identify major sources vary by regulatory program as discussed below. The Clean Air Act requirements are complex and voluminous. The discussion below is intended to provide an informative overview of the applicable requirements, not a detailed description of them.

As discussed in Sections 1.7 and 4.6.1.4, recovered CWM would be managed under the requirements of RCRA at some sites, under the requirements of CERCLA at other sites, and in some cases under a combination of the two programs. When the recovered CWM is managed in a transportable treatment system under RCRA, the RCRA action would need to comply with the requirements of the Clean Air Act and its implementing regulations that are discussed in this section, including the need to obtain necessary air permits. When the recovered CWM is managed in a transportable treatment system under CERCLA, the CERCLA action would need to comply with the substantive requirements of the Clean Air Act and its implementing regulations that are discussed in this section. However, CERCLA mandates that no federal, state, or local permit shall be required for the portion of any removal or remedial action conducted entirely on the CERCLA site, providing such remedial action is selected and carried out in accordance with CERCLA requirements. Thus, while the substantive requirements discussed below would apply, the need to obtain an air permit might not apply at CERCLA sites.

4.1.1 National Ambient Air Quality Standards

USEPA has established National Ambient Air Quality Standards (NAAQS) for several harmful air pollutants called criteria pollutants (40 CFR 50). The standards established for each individual pollutant define ambient air concentration levels not to be exceeded by that pollutant. The criteria pollutants are: carbon monoxide (CO), lead, nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and two sizes of particulate matter—PM_{10} (particulate matter less than 10 micrometers [μm] in diameter) and $PM_{2.5}$ (particulate matter less than 2.5 μm in diameter). Table 4-1 lists the NAAQS. States may set ambient air quality standards more stringent than the NAAQS—for example, Florida has set more stringent SO_2 standards—and may also set standards for additional pollutants—for example, several states have ambient air quality standards for fluorides.

There are two types of NAAQS—primary standards to protect public health and secondary standards to protect the public welfare from adverse effects associated with the presence of the air pollutant. Depending on the criteria pollutant, the standards apply to short-term concentrations of the pollutant (to help protect people from the adverse health effects associated with acute exposure to air pollution) and/or to long term concentrations (to protect the population from any adverse health effects due to chronic exposure to lower concentrations of air pollution).

To provide for adequate implementation of the NAAQS, the United States has been divided into air quality control regions (40 CFR 81). Areas within each air quality control region are designated as being an attainment, nonattainment, unclassifiable, or maintenance area for each criteria pollutant. An area in which the concentration of a criteria pollutant meets its NAAQS is designated as an attainment area for that criteria pollutant. An area in which the concentration of a criteria pollutant does not meet its NAAQS is designated as a nonattainment area for that criteria pollutant. An area can be an attainment area for some criteria pollutants and a nonattainment area for others. Any area that cannot be classified on the basis of available information as meeting or not meeting its NAAQS is designated as an unclassifiable area for that criteria pollutant. Maintenance areas are those areas that have been redesignated from nonattainment to attainment for a criteria pollutant and that have a maintenance plan approved under Section 175A of the Clean Air Act.

4.1.2 Preconstruction Permits and Requirements

New sources of air emissions generally require construction permits before they can be built and operating permits (see Section 4.1.3) before they can operate after being constructed. The permits are usually issued by the state (including Indian Tribes) or local air pollution control authority; however, in some cases USEPA is the permitting authority.

New major sources of air emissions (as defined below) and major modifications to existing sources are subject to federal New Source Review requirements before they can be

Table 4-1. National Ambient Air Quality Standards

Pollutant	Primary Standard		Secondary Standard	
	Averaging Time	Concentration	Type of Average	Concentration
Carbon monoxide (CO)	8-hour[a]	9 ppm (10 mg/m^3)	None	None
	1-hour[a]	35 ppm (40 mg/m^3)	None	None
Lead (Pb)	Maximum quarterly arithmetic mean	1.5 μg/m^3	Maximum quarterly arithmetic mean	1.5 μg/m^3
Nitrogen dioxide (NO_2)	Annual arithmetic mean[b]	0.053 ppm (100 μg/m^3)	Annual arithmetic mean[b]	0.053 ppm (100 μg/m^3)
Ozone (O_3)	8-hour[c,d]	0.08 ppm (157 μg/m^3)[e]	8-hour[c,d]	0.08 ppm (157 μg/m^3)
	1-hour	0.12 ppm (235 μg/m^3)	1-hour	0.12 ppm (235 μg/m^3)
Particulate matter (PM_{10})	Annual arithmetic mean[d,e]	50 μg/m^3	Annual arithmetic mean[d,e]	50 μg/m^3
	24-hour[d,e]	150 μg/m^3	24-hour[d,e]	150 μg/m^3
Particulate matter ($PM_{2.5}$)	Annual arithmetic mean[d,f]	15 μg/m^3	Annual arithmetic mean[d,f]	15 μg/m^3
	24-hour[d,f]	65 μg/m^3	24-hour[d,f]	65 μg/m^3
Sulfur dioxide (SO_2)	Annual arithmetic mean[b]	0.030 ppm (80 μg/m^3)	3-hour[a]	0.50 ppm (1,300 μg/m^3)
	24-hour[a]	0.14 ppm (365 μg/m^3)		

[a] This standard is not to be exceeded more than once per ye ar.

[b] This standard is not to be exceeded in a calendar year.

[c] The standard is based on the average of the fourth highest daily maximum 8-hour concentration during each ozone season (which varies by state) for each of three consecutive years.

[d] The 8-hour ozone standard and the revised particulate matter standards that became effective 16 September 1997 (62 FR 38652-38701) were set aside by a recent court decision; USEPA was directed to develop new standards (American Trucking Associations v. USEPA, DC Circuit, No. 97-1440 and 1441). The Department of Justice has announced it will appeal the ruling. The ultimate resolution is uncertain at this time. Until resolved, the previous NAAQS for PM_{10} and the previous 1-hour NAAQS for ozone remain in effect. There is no previous NAAQS for $PM_{2.5}$.

[e] The revised and previous standards specify the same limit. However, the revised annual standard is based on the average of the annual means over a three-year period. The revised 24-hour standard is based on the 99th percentile of values of the 24-hour concentrations. The previous annual standard is based on annual arithmetic mean and is not to be exceeded in a calendar year. The previous 24-hour standard is attained when the expected number of days per calendar year with 24-hour concentration above the standard is less than or equal to 1.

[f] The annual standard applies to the average of the annual arithmetic means over a three-year period. The 24-hour standard applies to the average of the 98th percentile of values of the 24-hour average concentrations over a three-year period. There is no previous standard.

Source: 40 CFR 50

constructed. The specific requirements of the New Source Review depend on emissions levels and whether the source is located in an attainment or nonattainment area; if an area is designated attainment for some criteria pollutants and nonattainment for others, the source could be subject to both types of New Source Review requirements. The federal New Source Review requirements are discussed below. States may also require permits and approvals for other new sources (or modifications) not subject to the federal New Source Review requirements. State air pollution control programs vary widely in their specific requirements, including the types of activities for which such air permits or approvals are required. Many state air regulations require air permits for any device or equipment capable of emitting an air contaminant or, in some cases, even for those controlling air contaminants.

4.1.2.1 Attainment Areas

Sources (and modifications to existing sources) that are to be constructed in attainment (and unclassifiable) areas are subject to New Source Reviews under the Prevention of Significant Deterioration (PSD) permit program requirements (40 CFR 51.166 or 52.21). The federal PSD program requirements are specified in 40 CFR 52.21; 40 CFR 51.166 specifies the minimum requirements that state programs must meet—most state program requirements tend to be very similar to the federal PSD program requirements. The PSD rules are intended to keep an area in which air quality standards are being met in compliance with those standards.

The PSD program requirements apply to any stationary source that emits, or has the potential to emit (as defined in the PSD regulations), 250 tons per year or more of any regulated pollutant. Such sources are defined as major stationary sources. (Major stationary sources also include certain specified sources that emit, or have the potential to emit, 100 tons per year, but these sources are not applicable to transportable treatment systems.) The stationary source can consist of either a single source (e.g., building, structure, facility) or a group of such sources providing that the group of sources are located within a contiguous area, are under common control, and belong to the same industrial grouping. For example, if a transportable treatment system were to be used on a military installation, the stationary source could include both the transportable treatment system and other applicable emission sources on the installation. USEPA has issued guidance on major source determinations for military installations, recognizing that military installations are different from most industrial sources (Seitz, 1996). The PSD program requirements also apply to major modifications to major stationary sources. Major modifications are any physical changes or changes in methods of operations at major stationary sources that would result in a significant net emissions increase (see Table 4-2) in any regulated pollutant. Certain emissions, such as those from constructing the source (or the modification) and those from mobile sources, are not considered in determining the net emissions increase.

Actual construction of an emissions source subject to the PSD regulations may not commence unless the source is issued a permit or approval that indicates the source would meet, at a minimum, requirements specified under 40 CFR 51.166(j) through (r) or under

40 CFR 52.21(j) through (r). This includes requirements for air modeling and air quality impact analysis; analysis of impacts to visibility, soils, and vegetation; and the use of best available control technology (BACT) for each pollutant that could be emitted in significant amounts. BACT, which is determined by the permitting authority on a case-by-case basis, means an emissions limitation based on the maximum degree of reduction achievable, taking into account energy, environmental, and economic impacts and other costs. The source also needs to meet each applicable emissions standard under the SIP and each applicable emissions standard and standard of performance under the New Source Performance Standards (NSPS, 40 CFR 60) and National Emission Standards for Hazardous Air Pollutants (NESHAPs, 40 CFR 61). Additional requirements (40 CFR 51.300) exist for the protection of visibility in those areas that are identified as mandatory Class I areas under the PSD requirements of the Clean Air Act. The congressionally-mandatory Class I areas consist of international parks, national wilderness areas that exceed 5,000 acres, national memorial parks that exceed 5,000 acres, and national parks that exceed 6,000 acres.

Table 4-2. Significant Emission Increases for New Source Reviews

Air Pollutant	Prevention of Significant Deterioration Program (tons per year)	Nonattainment New Source Review (tons per year)
Carbon monoxide	100	100
Nitrogen oxides	40	40
Ozone [a]	40[a]	40[a]
Sulfur dioxide	40	40
Particulate	25	NA
PM_{10}	15	NA
Hydrogen sulfide	10	NA
Total reduced sulfur	10	NA
Reduced sulfur compounds	10	NA
Sulfuric acid mist	7	NA
Fluorides (as HF)	3	NA
Vinyl chloride	1	NA
Lead	0.6	0.6
Mercury	0.1	NA
Asbestos	0.007	NA
Beryllium	0.0004	NA

[a]The quantity for ozone is based on the emissions of volatile organic compounds.

NA – Not applicable

Source: 40 CFR 51.165, 40 CFR 51.166, and 40 CFR 52.21

4.1.2.2 Nonattainment Areas

Sources (and modifications to existing sources) that are to be constructed in nonattainment (and unclassifiable) areas are subject to nonattainment New Source Reviews and, if the sources are implemented by federal actions (such as the deployment of a transportable treatment system), to conformity requirements under 40 CFR 51 Subpart W.

Nonattainment New Source Review. Nonattainment New Source Reviews are state programs that must meet the minimum requirements specified in 40 CFR 51.165. Nonattainment New Source Reviews are intended to assist areas in their efforts to attain and maintain compliance with the NAAQS.

The nonattainment New Source Review program requirements apply to any stationary source that emits, or has the potential to emit (as defined in the regulations), 100 tons per year or more of any regulated pollutant. Such sources are defined as major stationary sources. Stationary sources have the same definition as under the PSD program. (USEPA guidance on identifying major sources at military installations, discussed under the PSD program, also applies to the nonattainment New Source Review program.) The nonattainment New Source Review program requirements also apply to any physical change that would occur at a stationary source not otherwise qualifying as a major stationary source, if the change would constitute a major source by itself. The program requirements also apply to major modifications to major stationary sources. Major modifications are any physical changes or changes in methods of operations at major stationary sources that would result in a significant net emissions increase (see Table 4-2) in any regulated pollutant. Certain emissions, such as those from the construction of either the source or the modification and those from mobile sources, are not considered in determining the net emissions increase.

Actual construction of an emissions source subject to the nonattainment New Source Review requirements may not commence unless the source is issued a permit or approval. This includes requirements for air modeling and air quality impact analysis; emission offsets; alternative site analysis; and the use of the lowest achievable emission rate (LAER) for each pollutant that could be emitted in significant amounts. LAER, which is determined by the permitting authority on a case-by-case basis, is essentially the most stringent emission limitation achieved in practice by such class or category of source without taking into account energy, environmental and economic impacts and other costs, with certain narrowly defined exceptions. Emission offsets are emission reductions that counterbalance the increase from the proposed source. The source also needs to meet each applicable emissions standard under the SIP and each applicable emissions standard and standard of performance under NSPS (40 CFR 60) and NESHAPs (40 CFR 61).

Conformity. The General Conformity Rule under 40 CFR 51 Subpart W applies to federal actions in nonattainment (and maintenance) areas. The rule is intended to ensure that federal actions conform to the purpose of SIPs and do not cause or contribute to new

violations of NAAQS, increase the severity or frequency of existing violations, or otherwise delay attainment.

The General Conformity Rule applies only to those criteria pollutants for which the area is in nonattainment. The rule requires a conformity determination for each such criteria pollutant for which the total of direct and indirect emissions caused by the federal action equals or exceeds specified minimum rates. (Direct and indirect emissions include emissions from both mobile and stationary sources.) The applicable rates vary according to both the criteria pollutant and its level of nonattainment in the area and range from 10 to 100 tons per year. For the criteria pollutant ozone, emissions of nitrogen oxides and volatile organic compounds (which lead to the formation of ozone) are used in the comparison. Direct emissions from remedial and removal actions carried out under CERCLA —for example, the use of a transportable treatment system as part of a CERCLA remedial or removal action—are exempt from a conformity determination to the extent that the emissions comply with the substantive requirements of the Prevention of Significant Deterioration program and the nonattainment New Source Review program or are exempted from other environmental regulations under the provisions of CERCLA.

Federal actions producing total direct plus indirect emissions below the minimum levels are considered to conform to the SIP. Federal actions producing total direct plus indirect emission at or above the minimum levels are required to perform a conformity determination as outlined in the General Conformity Rule. Only those actions that are determined to conform can be undertaken by the federal agency.

4.1.3 Operating Permits

New sources of air emissions generally require operating permits before they can operate after being constructed. The permits are usually issued by the state (including Indian Tribes) or local air pollution control authority; however, in some cases USEPA is the permitting authority.

The Clean Air Act Amendments of 1990 added Title V to the Clean Air Act. Title V has the intent of integrating federal requirements under various control programs into a single permit program—the Title V operating permit. Under Title V, a stationary air emission source that is subject to federal standards, regulations, or permits cannot be operated unless it is in compliance with a permit issued under Title V. Title V requires each state or eligible Indian Tribe to establish and administer a Title V permit program that at least meets the minimum requirements specified in 40 CFR 70; the state permit is typically called a Part 70 permit. If a state program is not approved by USEPA within a specified timeframe, Title V requires USEPA to run the Title V program in the state; the federal permit program requirements are specified in 40 CFR 71.

Title V permits are required for a variety of sources, including major sources, as defined below, and most sources subject to NSPS (40 CFR 60), NESHAPs (40 CFR 61), or

NESHAPs for Source Categories (40 CFR 63). Major sources under Title V are defined to include any stationary source or group of stationary sources located within a contiguous area and under common control that emits or has the potential to emit at least 10 tons per year of any single hazardous air pollutant (HAP) or 25 tons per year of all HAPS combined. (Almost 190 pollutants have been identified as HAPs pursuant to Section 112[b] of the Clean Air Act.) Major sources also include stationary sources that emit or have the potential to emit at least 100 tons per year of any regulated air pollutant. In addition, majo r sources include stationary sources that have the potential to emit specified quantities of nitrogen oxides, volatile organic compounds, carbon monoxide, or PM_{10} in nonattainment areas. The quantities vary according to both the criteria pollutant and its level of nonattainment in the area and range from 10 to 100 tons per year. USEPA guidance on identifying major sources at military installations, discussed under the PSD program, also applies to the Title V permit program. In addition, USEPA has concluded that "permitting authorities have the discretion to issue more than one title V permit to each major source at an installation, so long as the collection of permits ensures that all applicable requirements would be met that otherwise would be required under a single permit for each major source" (Seitz, 1996).

Each Title V operating permit must include various specified requirements, including the following items:

- Descriptions of sources of emissions (processes, equipment, and points of emissions)
- Emission limits and standards
- Schedules for compliance and operating/processing conditions
- Monitoring and related recordkeeping and reporting requirements (schedules, parameters, and methods)
- A permit duration of no more than five years.
- Provisions for inspection and entry by the permitting authority

In addition, as discussed for construction permits, states may also require operating permits and approvals for other new sources (or modifications) not subject to the Title V requirements. Again state air pollution control programs vary widely in their specific requirements, including the types of activities for which such air permits or approvals are required.

4.1.4 Accident Prevention Provisions

Certain hazardous substances that can be accidentally released into the environment from stationary sources are regulated under Section 112(r) of the Clean Air Act. The Chemical Accident Prevention Provisions (40 CFR 68) specify the list of regulated substances, the threshold quantities at which these substances are subject to regulation, and the requirements for owners and operators of stationary sources with regard to preventing accidental releases of those substances that are present above their specified thresholds. The regulated substances consist of 77 toxic substances, 63 flammable gases and volatile liquids, and

certain high explosives. Some of the regulated substances, such as chloroform, cyanogen chloride, and isobutane, may be present in small quantities at transportable treatment system sites. The threshold quantities at which the Chemical Accident Prevention Provisions would apply to such substances range between 500 to 20,000 pounds, depending on the substance.

Stationary sources that have more than the threshold quantity of any substance present would, at a minimum, need to prepare a Risk Management Plan that complies with the requirements in 40 CFR 68.150 through 68.185, analyze the worst-case release scenario for the relevant processes, complete a five-year accident history for the relevant processes, ensure that response actions have been coordinated with local emergency planning and response agencies, and make certain required certifications. Certain facilities that have had releases of regulated substances within the past five years would also need to conduct a hazard assessment.

The accident prevention requirements complement EPCRA reporting and planning requirements (see Section 4.14).

4.1.5 Additional Air Regulations Applicable to Disposal of Wastes from a Transportable Treatment System

The life-cycle activities associated with a transportable treatment system would generate various wastes, some of which would be a RCRA hazardous waste and some of which would be a nonhazardous waste. Section 3.1.10 identifies the various wastes that would be generated and the types of facilities where each waste would be managed. The facilities could include permitted, commercial, RCRA hazardous waste TSDFs; permitted solid waste management facilities; wastewater treatment facilities; and recycling facilities. Some of these facilities could be subject to facility-specific air regulations that are in addition to the air regulations discussed above. These facility-specific air regulations are discussed under waste management (Section 4.6).

4.2 Noise

During site preparation and system setup there could be impacts associated with increased noise levels. Potential sources of noise include construction equipment that may be used in site preparation activities; heavy and light duty trucks, helicopters, and fixed-wing aircraft used in transport of people, equipment, and non-stockpile CWM for off-property treatment; and diesel-powered electric generators and air-handling equipment used during treatment operations.

Sound level is usually measured and reported terms of a logarithmic scale in units of decibels (dB). A small increase in decibels can represent a large increase in sound energy. An increase of 3 dB represents a doubling of sound energy, and an increase of 10 dB represents a tenfold increase. The human ear, however, can only moderately detect a 3 dB increase and perceives a 10 dB increase as doubling of loudness (Army Technical Manual 5-803-2).

The human ear is not equally sensitive to sound levels at all frequencies. Humans are more sensitive to high frequency (>1000 Hz) sound than to mid or low frequency (<125 Hz) sound (Army Technical Manual 5-803-2). Because of this variability, a frequency-dependent weighting function, known as A-weighting, has been devised which approximates the response of the human ear. The A-weighted sound level is reported as "dBA". For high amplitude, short duration impulse-type noises such as explosions, artillery firing, and helicopters, a different integrating function known as C-weighting is used (Army Technical Manual 5-803-2; Schomer, 1982).

The range of ambient noise levels in areas where the mobile treatment systems might be deployed will vary with the type of land use, development, population density, and other noise sources existing in those areas. Environmental settings could range from rural sites with low ambient or occupational sound levels to industrial urban areas with high ambient or occupational noise levels and numerous noise sources. Noise levels in metropolitan or urban areas generally exceed that of suburban or rural areas. Thus, a wide range of noise environments could be encountered.

A wide range of noise sources and levels are typical of military bases. Military training courses and field exercises which use vehicles, weapons, or machinery create noise for operators, military, and civilian personnel, and in large-scale exercises can affect nearby communities. High performance aircraft, helicopters, and heavy weapons are the most intrusive (Jain et al., 1993). Military bases that generate excessive noise are required to establish programs to determine the compatibility of land use in the areas affected by obtrusive noises. These programs include the Environmental Noise Management Program and Air Installation Compatible Use Zones described in Chapter 7 of AR 200-1.

Federal, state, and local governments have promulgated noise control regulations and guidelines for the protection of human health and the environment. Noise guidelines are either source or ambient based. Source regulations or guidelines pertain to specific noise sources (such as equipment or consumer products). Ambient guidelines are those that protect individuals from noise pollution regardless of the source or origin of the noise. Noise guidelines have been issued by the USEPA, Federal Aviation Administration (FAA), DoD, the Department of Housing and Urban Development (HUD), the Federal Highway Administration, the Occupational Safety and Health Administration, and the Federal Railroad Administration.

According to Army, FAA, and HUD criteria, residential units and other noise-sensitive land uses are "clearly unacceptable" in areas subject to noise exposure levels exceeding Leq[1] of 75 dBA; "normally unacceptable" in areas exposed to Leq between 65 and 75 dBA;

[1] Equivalent Sound Level: The equivalent sound level is obtained by averaging (on an energy-weighted basis) the A-weighed sound levels over a selected time period. It is the continuous noise level that is equivalent, on an energy basis, with a noise signal that fluctuates over time. The typical averaging period is one hour.

and "normally acceptable" in areas exposed to Leq of 65 dBA or less (Army Technical Manual 5-803-2). Some states and many local jurisdictions have also established noise control regulations and ordinances. In general, these requirements also focus on an Leq of 65 dBA as the maximum acceptable noise exposure level permitted at sensi tive receptor sites. AR 200-1 specifies a DNL[2] of 65 dBA as an acceptable noise level for outdoor exposures at residential and other noise sensitive locations. These criteria refer to noise levels experienced at the receptor.

4.3 Geology, Minerals, and Soils

Site preparation and setup, operation, and subsequent demobilization of the mobile treatment systems could potentially affect the geological, mineral, or soil resources at the locations where these systems are deployed. Operations at a treatment site could affect access to economically important minerals, alter soil structures, or cause loss of soils through erosion.

Protection of surface and subsurface mineral and soil resources is governed by only a few federal regulations. The two principal ones are discussed below.

Prime and unique farmlands are protected by Section 388 of Title III of the 1996 Federal Agriculture Improvement and Reform Act. The purpose of this program is to protect soil by limiting nonagricultural use of prime and unique farmland. It may also require creation of a conservation plan to protect highly erodible cropland.

The Farmland Protection Policy Act and the U.S. Department of Agriculture's implementing procedures require federal agencies to evaluate the adverse effects (direct and indirect) of their activities on prime and unique farmland, as well as farmland of statewide and local importance. Alternative actions that would avoid potential adverse effects must be considered.

4.4 Groundwater

Groundwater resources are protected by a variety of federal and state regulations. For example, the Safe Drinking Water Act established the sole source aquifer program to identify critical aquifer protection areas that are eligible for protected status under state or local authority. States consequently instituted wellhead protection programs to protect groundwater recharge areas and to limit projects with the potential to impact groundwater. Each location at which a mobile treatment system is deployed would have to be evaluated to determine if the proposed activity was located in a wellhead protection area and, if so, whether that activity was consistent with acceptable uses.

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[2] Day-Night Sound Level – The A-weighted equivalent sound level for a 24-hour period, with a 10 dB penalty imposed on sound levels during nighttime (10 PM to 7 AM).

Several states have also enacted anti-degradation laws to protect the quality of existing groundwater. Thus, impacts to groundwater can be prohibited even if those impacts do not degrade groundwater quality below current usage.

RCRA and CERCLA are important federal statutes protecting groundwater and requiring remediation of contaminated groundwater.

4.5 Ecological Environment

The ecological environment affected by the setup, operation, and demobilization of the mobile treatment systems would depend upon specific siting decisions, but certain regulatory requirements created to protect the natural environment would apply regardless of the ultimate location of the treatment systems. Some major laws and regulations are discussed in the following sections.

4.5.1 Upland Environment

As the mobile treatment systems are deployed, site-specific determinations will be required to determine the impact of the systems on the upland environment. This environment includes the flora and fauna living in and on the surface, and such environments as parklands, wilderness areas, Nature Conservancy areas, and similar lands. Unlike other environments, terrestrial environments are not directly addressed or protected by statute, although certain activities are prohibited in wilderness areas, National Parks and Forests, and other managed lands. Additionally, the biota receive federal protection if they are threatened or endangered species.

4.5.2 Wetlands and Floodplains

Wetlands are regulated by the U.S. Army Corps of Engineers and USEPA. A principal regulation governing wetlands is Section 404 of the Clean Water Act, which generally prohibits dredge and fill operations in wetlands.

In addition, federal agencies are required under Executive Order 11990, Protection of Wetlands, to avoid, if possible, adverse impacts to wetlands and to preserve and enhance the natural and beneficial values of wetlands.

The purpose of Executive Order 11990 is to "minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands." To meet these objectives, the Order requires federal agencies, in planning their actions, to consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. The Order applies to:

- Acquisition, management, and disposition of federal lands and facilities construction and improvement projects which are undertaken, financed or assisted by federal agencies

- Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulation, and licensing activities

Executive Order 11988, Floodplain Management, requires federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities" for the following actions:

- Acquiring, managing, and disposing of federal lands and facilities
- Providing federally-undertaken, financed, or assisted construction and improvements
- Conducting federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulation, and licensing activities

4.5.3 Aquatic Environment

Impacts to consider in aquatic environments include those on drinking water supplies and those that affect biota. Contaminants affecting taste or toxicity are not the only possible effect. Water quality parameters such as turbidity, flow, and temperature should also be monitored.

The Safe Drinking Water Act of 1974, as amended, was enacted to protect the quality of public water supplies and all sources of drinking water. Regulations issued under the Safe Drinking Water Act identify maximum pollutant levels that can be contained in public water systems, which are defined as water systems that serve at least 15 service connections used by year-round residents or regularly serve at least 25 year-round residents. The Clean Water Act also called the Federal Water Pollution Control Act, was enacted to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The primary goals of the Act are to achieve water quality levels that protect and propagate fish, shellfish, and wildlife; support recreation in and on the water; and eliminate the discharge of pollutants into navigable waters. USEPA measures progress in achieving water quality levels by summarizing attainment of state and tribal water quality standards. States may adopt water quality standards more stringent than federal standards, but not less stringent. Water quality standards consist of designated beneficial uses, numeric and narrative criteria to protect uses of surface water, and anti-degradation policy statements. These types of water quality standards (referred to more commonly as water quality criteria) are described below.

Designated beneficial uses are the desirable uses that water quality can support. These include drinking water supply, primary contact recreation (that is, swimming), and aquatic life support. Each designated use has a unique set of water quality requirements or criteria

that must be met for the use to be realized or attained. Specific water bodies may have multiple designated uses.

Numeric water quality criteria establish the minimum physical, chemical, and biological parameters required to support a beneficial use. Physical and chemical numeric criteria may set maximum concentrations of pollutants, acceptable ranges of physical parameters (such as flow and temperature), and minimum concentrations of desirable parameters (such as dissolved oxygen).

Narrative water quality criteria define, rather than quantify, conditions and attainable goals that must be maintained to support a designated use.

Anti-degradation policy statements protect existing uses and prevent water bodies from deteriorating even if their water quality is better than the fishable and swimmable goals of the Clean Water Act.

Discharges to surface waters are regulated under the Clean Water Act's National Pollutant Discharge Elimination System. Under this system, permits are required before a discharge can occur. These permits limit the amount and types of specific pollutants that can be discharged into surface waters. Section 301(f) of the Clean Water Act prohibits the discharge of chemical warfare agents into navigable waters.

4.5.4 Threatened and Endangered Species

The purpose of the Endangered Species Act is to ensure that federal agencies and departments use their authorities to protect and conserve endangered and threatened species. Section 7 of the Act requires that federal agencies prevent or modify any projects authorized, funded, or carried out by the agencies that are "likely to jeopardize the continued existence of any endangered species or threatened species, or result in the destruction or adverse modification of critical habitat of such species." The Act is implemented through the following regulations:

- 50 CFR Part 402: Department of Interior and Department of Commerce procedures for implementing Section 7.
- 50 CFR Parts 450, 451, 452, and 453: Department of Interior and Department of Commerce rules for applying for Endangered Species Act exemptions and Endangered Species Committee consideration of such applications.

Federal agencies must review actions they undertake or support to determine whether they may affect threatened or endangered species or their habitats. If such review reveals the potential for effects, the federal agency must consult with the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS), as appropriate. Consultation is carried out for the purpose of identifying whether a federal action is likely to jeopardize the continued existence of the endangered or threatened species or adversely affect its critical habitat. If USFWS or NMFS determines that a proposed action would likely have this

negative impact, then the project must be stopped unless the consulting parties can agree on alternatives to eliminate jeopardy. If there are no feasible alternatives that can be carried out, the action agency may apply for an exemption with the Endangered Species Committee.

The determination of the presence or absence of an endangered or threatened species or habitat cannot be made until a decision on deployment at a specific location has been made.

4.6 Waste Management

The Army intends to manage all CWM considered in this environmental impact statement as a hazardous waste even if some of it does not meet the RCRA definition of a hazardous waste (see Section 1). Discussed below are the waste management requirements that would apply in using a transportable treatment system to treat the CWM. When used to treat this CWM, the transportable treatment system would be considered a hazardous waste TSDF and would have to comply with RCRA requirements applicable to hazardous waste TSDFs.

Treatment of the CWM would generate additional wastes, some of which would be hazardous waste and some of which would not be hazardous waste. Section 3 identifies the various wastes that would be generated and the type of facility where each waste would be managed. The facilities could include permitted, commercial, RCRA hazardous waste TSDFs; permitted solid waste management facilities; wastewater treatment facilities; and recycling facilities. The waste management requirements applicable to managing these hazardous and non-hazardous wastes at these types of facilities are also discussed in this section.

The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

The discussion in this section focuses on the federal waste management programs applicable to the following types of facilities:

- Hazardous waste management facilities
- Municipal solid waste landfills
- Municipal solid waste incinerators
- Wastewater treatment facilities
- Recycling facilities

Corresponding state regulations often incorporate additional requirements or alternative, but equivalent, requirements to those specified under the federal program. Such requirements vary greatly among states. The management of all waste associated with the use of transportable treatment systems would be carried out in accordance with all federal, tribal,

state, and local laws and requirements applicable at a specific site. These would be addressed in the site-specific analyses and documentation prepared for each site.

Waste management would also have to comply with Army regulations discussed in this section.

4.6.1 RCRA Hazardous Waste Management Requirements

Subtitle C of RCRA establishes a national system and standards for the "cradle-to-grave" control of hazardous waste and applies to all entities managing hazardous waste. The RCRA standards apply to any activity that generates, transports, treats, stores, or disposes of hazardous waste, with certain specified exceptions.

The RCRA program in any particular state may be run by the federal USEPA, by the state when authorized by USEPA to do so, or by a combination of the state and USEPA. When run by USEPA, the federal RCRA laws and regulations (40 CFR 260-270) apply, and USEPA is responsible for administering and enforcing the program, including issuing permits for treatment, storage, and disposal. When run by a particular state, the state RCRA laws and regulations apply, and the state is responsible for administering and enforcing the program, including issuing permits. When run by a combination of the two, federal laws and regulations apply for the portion run by USEPA, and state laws and regulation apply for the portion run by the state. USEPA would issue the permits applicable to the portion it runs, and the state would issue the permits applicable to the portion it runs. For the most part, state RCRA requirements are essentially identical to the federal requirements. Where they differ, they often provide equivalent protection through an alternative means.

The current federal RCRA requirements that could apply to managing the CWM considered in this environmental impact statement are described below. The discussion focuses on the following requirements:

- Transport requirements
- Treatment, storage, and disposal requirements
- Land disposal restrictions
- CERCLA requirements

The RCRA regulations are complex and voluminous. The discussion below is intended to provide an informative overview of the regulations, not a detailed description of them.

4.6.1.1 Transport Requirements

CWM may at times be transported to an off-property location for treatment in a transportable treatment system (see Section 3). In addition, hazardous waste generated from treating CWM in a transportable treatment system would also be transported off-property for management at a permitted, commercial hazardous waste TSDF. Transport of the CWM (and/or the waste generated from its treatment) would have to comply with RCRA transport

requirements under 40 CFR 263. These requirements are discussed in Section 4.8. That section also discusses applicable Hazardous Materials Transportation Act (HMTA) regulations.

4.6.1.2 Treatment, Storage, and Disposal Requirements

When used to treat CWM, a transportable treatment system would be considered a hazardous waste TSDF and would have to comply with RCRA requirements for hazardous waste TSDFs. The transportable treatment system would have to obtain a RCRA permit before it could be set up and used to treat CWM at a specific site (see Section 1.7). A separate permit would be required at each site at which the transportable treatment system was to be used. Furthermore, any hazardous waste generated by the operation of the transportable treatment system would have to be managed at a permitted hazardous waste TSDF.

The permit is intended to ensure that hazardous waste TSDFs, including transportable treatment systems, are constructed and operated in accordance with RCRA regulations. The permit specifies all of the particular conditions that apply to a facility, including the specific hazardous wastes it can manage, the specific RCRA regulations with which it must comply, whether the facility can receive waste from offsite or from out-of-state, and the expiration date of the permit. A hazardous waste TSDF may only manage those wastes that are specifically listed in its permit, and it must manage them only in ways that comply with the requirements and conditions specified in its permit. The RCRA permit regulations (40 CFR 270) establish standards for the permit application (including information that must be included on the permit application), permit issuance, permit modification, permit revocation, and permit duration, as well as requirements for public participation in the permitting process.

In addition to obtaining a RCRA permit, a hazardous waste TSDF must comply with two types of standards: (1) general standards applicable to all hazardous waste facilities and (2) facility-specific standards applicable to specific types of treatment, storage, and dispos al units at a facility (e.g., landfill, storage containers, various treatment units). General standards contain requirements for siting of hazardous waste facilities as well as for security, inspections, waste analysis, training, preparedness and prevention, contingency plans and emergency preparedness, and facility closure and post-closure activities. Facility-specific standards include requirements for the design, operation, and location of the treatment, storage, or disposal unit, as well as for monitoring and detecting releases from the unit, for responding to any such releases, and for closure of the unit.

RCRA requirements that would be applicable to each of the following activities are discussed below:

- Use of a transportable treatment system
- Storage of hazardous waste on the treatment site
- Management of hazardous waste at a commercial hazardous waste TSDF

Use of a Transportable Treatment System. When used to treat CWM, a transportable treatment system would be classified as a miscellaneous unit under RCRA. A miscellaneous

unit is defined under 40 CFR 260.10 as a hazardous waste management unit that is not specifically a container, tank, surface impoundment, pile, land treatment unit, landfill, incinerator, boiler, industrial furnace, underground injection well, containment building, corrective action management unit, or eligible research, development, or demonstration unit.

As a miscellaneous unit, a transportable treatment system would be subject to the RCRA standards for miscellaneous units (40 CFR 264 Subpart X) as well as to the general standards. The Subpart X standards require compliance with permit conditions necessary to protect human health and the environment. These permit conditions are to be developed for each particular unit and site on a site-by-site basis and are to include location, design, operating, monitoring and detection, release response, and closure and post-closure requirements. Closure requirements would specify, among other provisions, the level to which the transportable treatment system must be decontaminated before it could be transported offsite after closure of the system.

Storage of Hazardous Waste on the Treatment Site. RCRA storage requirements depend on the length of time that hazardous waste is stored on the site. If the hazardous waste is stored for 90 days or less, the storage does not require a permit if certain RCRA storage requirements—specified under 40 CFR 262.34 and discussed below—are met and if all hazardous waste is removed from the site at least once every 90 days or less. (This 90-day storage exemption is increased to 180 or 270 days for small quantity generators as defined under 40 CFR 261.5). If hazardous waste storage exceeds 90 days and/or does not comply with the 40 CFR 262.34 requirements, the generator must obtain a permit and comply with more stringent storage requirements discussed below. The Army does not expect to store hazardous waste generated from treating CWM in a transportable treatment system for more than 90 days.

To qualify for the 90-day storage exemption, the storage must take place in a container, tank, containment building, or on drip pads that comply with 40 CFR 262.34 requirements. These requirements apply to the design and operation of the storage unit, as well as to recordkeeping, inspections, containment and detection of releases, response to releases, control of air emissions, and closure of the storage unit. These storage requirements are somewhat less stringent than those that would apply to storage exceeding 90 days.

If hazardous waste storage exceeds 90 days and/or does not comply with the 40 CFR 262.34 requirements, the generator must obtain a storage permit and comply with the RCRA general standards and facility-specific standards. The facility-specific standards include container standards (40 CFR 264 Subpart I); tank system standards (40 CFR 264 Subpart J); air emission standards for tanks, surface impoundments, and containers (40 CFR 264 Subpart CC); containment building standards (40 CFR 264 Subpart DD); and/or standards for hazardous waste munitions and explosives storage (40 CFR 264 Subpart EE). These standards include requirements for the location, design, and operation of the storage area, storage structure (such as an interim holding facility), container, and/or tank, as well as

requirements for inspections, containment and detection of releases, response to releases, control of air emissions from tanks and containers, and closure of the storage unit.

Management of Hazardous Waste at a Commercial Hazardous Waste TSDF. As previously indicated, hazardous waste would be generated in the operation of the transportable treatment systems. This hazardous waste, plus certain additional wastes identified in Section 3, would be transported off the treatment site for subsequent treatment and/or disposal at a permitted, commercial hazardous waste TSDF. The specific facilities that would be used and the specific treatment and/or disposal methods that would be applied at each commercial facility would be determined on a site-specific basis. This determination would depend in part on the site-specific nature and composition of the various hazardous waste streams generated.

Treatment and disposal of the waste at the commercial hazardous waste TSDFs would be carried out in accordance with all applicable RCRA requirements. As discussed below under land disposal restrictions, some of the waste would require treatment before it could be disposed while some could be disposed of in a hazardous waste landfill without any further treatment. Based on the discussion below, treatment methods that could be used include combustion, wet air oxidation, chemical or electrolytic oxidation, carbon adsorption, and deactivation. The specific treatment method used would be determined on a site-specific and waste-specific basis and would depend on the specific composition of the waste stream being managed. If incineration were used as the combustion treatment method, treatment would have to comply with the requirements under 40 CFR 264 Subpart O as discussed below. Treatment using the other methods would have to comply with the RCRA standards for miscellaneous units (40 CFR 264 Subpart X) that are discussed above. Standards for containers, tanks, surface impoundments, and air emissions discussed above under on-site storage could also apply to these other treatment methods. Disposal of waste in a hazardous waste landfill would have to comply with landfill requirements under 40 CFR 264 Subpart N. These landfill standards include requirements for landfill design, operation, monitoring and inspection, response actions, and closure and post-closure care. The general standards discussed above would also apply in all cases.

For an incinerator, operating requirements would be specified on a site-by-site basis in the RCRA permit. These operating requirements are established by the permitting authority, based on either the results of a trial burn or alternative data included in the permit application. The incineration standards under 40 CFR 264 Subpart O include requirements that the unit must be operated in accordance with the operating requirements specified in the permit and that the unit must be designed, constructed, and maintained so that, when operated in accordance with the operating requirements, it meets specified performance standards for destruction and removal of hazardous constituents in the waste. Monitoring, inspection, and closure requirements also apply.

In addition to these RCRA requirements and the Clean Air Act requirements discussed in Section 4.1, hazardous waste combusters could also be subject to National Emission Standards

for Hazardous Air Pollutants from Hazardous Waste Combusters (40 CFR 63 Subpart EEE). Almost 190 pollutants have been identified as HAPs pursuant to Section 112(b) of the Clean Air Act. Some of these HAPS, such as arsenic, benzene, and chloroform, may be present, usually in small quantities, in wastes from the transportable treatment systems. USEPA has promulgated some standards under 40 CFR 63 Subpart EEE and proposed others. One of the proposed standards (61 FR 17358) addresses maximum achievable control technology (MACT) standards for hazardous waste combusters that emit at least 10 tons per year of a single HAP or 25 tons per year of any combination of HAPs; the proposed standard also provides for coordinated Clean Air Act and RCRA permitting of hazardous waste combusters. USEPA has indicated that it is considering significant changes to various aspects of the proposed MACT standards (62 FR 24212).

A hazardous waste TSDF may manage only those wastes that are specifically listed in its permit; it may not manage other wastes that are not listed in its permit. In addition, the hazardous wastes must be managed only in ways that comply with requirements and conditions specified in the facility's permit.

The NSCMP has in place a program of auditing and review of TSDFs that treat NSCMP wastes. This program would apply to TSDFs that accept and treat wastes from the transportable treatment systems. In selecting a specific, permitted, commercial TSDF to receive Army wastes, the Army would consider the past compliance history of the facility and the type of monitoring and pollution control equipment in use at the facility. The Army would also perform continuing assessments and audits of the performance of all hazardous waste TSDFs selected to ensure that these facilities remain in compliance with all applicable environmental regulations and safety requirements.

4.6.1.3 Land Disposal Restrictions

RCRA places restrictions on the land disposal of certain hazardous wastes. Land disposal is defined as the placement of a hazardous waste in or on the land and includes, but is not limited to, placement in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome or salt bed formation, or underground mine or cave. RCRA regulations under 40 CFR 268 identify those hazardous wastes restricted from land disposal and define the limited circumstances under which an otherwise prohibited waste may be land disposed.

A prohibited waste may be land disposed only if it meets treatment standards specified in 40 CFR 268. The treatment standards identify the following:

- A specific technology (or technologies) that must be used to treat the waste before it can be land disposed
- A maximum concentration level for each of the RCRA hazardous constituents in the waste or its treatment residue (or in an extract from the waste or residue if applicable) before it can be land disposed
- In some cases, both a treatment technology and a maximum concentration level

An alternative treatment technology can be used in place of a RCRA-specified treatment technology only if approved by the regulatory authority under procedures identified in the RCRA regulations.

Various hazardous wastes from the transportable treatment systems would be subject to the land disposal restrictions. These include the neutralent wastes, repackaged industrial chemicals, and spent filters. Some wastes, such as some industrial chemicals, would be subject to the land disposal restrictions because they are RCRA-listed wastes. Other wastes, such as neutralents, would be subject to the land disposal restrictions because they contain RCRA hazardous constituents and/or exhibit the RCRA hazardous characteristics of ignitability, reactivity, or corrosivity.

Table 4-3 identifies the treatment standards that would apply to wastes that contain RCRA hazardous constituents; wastes that are ignitable, reactive, or corrosive; and wastes that are RCRA-listed wastes, such as some industrial chemicals. The table also lists the RCRA code (e.g., D001) assigned to each constituent, characteristic, or listed waste. The RCRA hazardous constituents included in Table 4-3 are those that have been identified as potentially present in neutralent waste (see Tables 3-8 through 3-12). Where specific treatment technologies are identified in Table 4-3, the table only lists the RCRA technology code for the technology (e.g., CMBST). Table 4-4 identifies the technology-based standards that are encompassed by each technology code in Table 4-3.

The treatment standards in Table 4-3 differ based on whether the waste is a wastewater or a nonwastewater. A wastewater is defined as a waste that contains less than one percent by weight total organic carbon and less than one percent by weight total suspended solids (40 CFR 268.2[f]). A nonwastewater is defined as any waste that does not meet the definition of a wastewater (40 CFR 268.2[d]).

4.6.1.4 CERCLA Requirements

Recovered CWM would be managed under the requirements of RCRA at some sites, under the requirements of CERCLA at other sites, and in some cases under a combination of the two programs. When the recovered CWM is managed in a transportable treatment system under CERCLA, the requirements—that is, the applicable or relevant and appropriate requirements (ARARs)—that would apply would be specified in the remedy selection process for the site (see Section 1.7). The principal ARAR that would be applied would be the substantive requirements of RCRA, which are described above; a RCRA permit would not be needed. If the CWM and/or the waste generated from its treatment are subsequently transported off of the designated CERCLA on-site area (as defined in Section 1.7.2), its management, starting at that point in time, is considered to be off-site and is no longer subject to CERCLA, but rather becomes subject to all other applicable laws and regulations, including RCRA and the other laws and regulations discussed throughout Section 4.

Table 4-3. RCRA Land Disposal Treatment Standards

Waste Description	RCRA Waste Code	Treatment Standard[a]	
		Wastewater[b] (technology code[d]; or concentration in mg/l)	**Nonwastewater**[c] (technology code[d]; or concentration in mg/kg, unless noted as "mg/l TCLP")
RCRA Hazardous Constituents			
Organics			
Benzene	D018	0.14[e]	10[e]
Carbon tetrachloride	D019	0.057[e]	6.0[e]
Chloroform	D022	0.046[e]	6.0[e]
1,2-Dichloroethane	D028	0.21[e]	6.0[e]
1,1-Dichloroethylene	D029	0.025[e]	6.0[e]
2,4-Dinitrotoluene	D030	0.32[e]	140[e]
Hexachlorobenzene	D032	0.055[e]	10[e]
Hexachlorobutadiene	D033	0.055[e]	5.6[e]
Hexachloroethane	D034	0.055[e]	30[e]
Methyl ethyl ketone	D035	0.28[e]	36[e]
Pentachloroethane	U184	CMBST; or 0.055; or (WETOX or CHOXD) followed by CARBN	CMBST; or 6.0
1,1,1,2-Tetrachloroethane	U208	0.057	6.0
1,1,2,2-Tetrachloroethane	U209	0.057	6.0
Tetrachloroethylene	D039	0.056[e]	6.0[e]
Trichloroethylene	D040	0.054[e]	6.0[e]
1,1,2-Trichloroethane	U227	0.054	6.0
Vinyl chloride	D043	0.27[e]	6.0[e]
Metals			
Arsenic	D004	1.4[e]	5.0[e] mg/l TCLP
Barium	D005	1.2[e]	21[e] mg/l TCLP
Cadmium	D006	0.69[e]	0.11[e] mg/l TCLP
Chromium	D007	2.77[e]	0.60[e] mg/l TCLP
Lead	D008	0.69[e]	0.75[e] mg/l TCLP
Mercury	D009	0.15[e]	e, g
Nickel	NA	NA	NA
Selenium	D010	0.82[e]	5.7[e] mg/l TCLP
Silver	D011	0.43[e]	0.14[e] mg/l TCLP

Table 4-3. (Concluded)

Waste Description	RCRA Waste Code	Treatment Standard[a]	
		Wastewater[b] (technology code[d]; or concentration in mg/l)	Nonwastewater[c] (technology code[d]; or concentration in mg/kg, unless noted as "mg/l TCLP")
RCRA Characteristic Waste			
Ignitability (<10% total organic carbon)	D001	DEACT[e]; or RORGS; or CMBST	DEACT[e]; or RORGS; or CMBST
Ignitability (≥10% total organic carbon)	D001	NA	RORGS; CMBST; or POLYM
Corrosivity	D002	DEACT[e]	DEACT[e]
Reactivity	D003	DEACT[e]	DEACT[e]
Toxicity	D004-D011, D018-D019, D022, D028-D030, D032-D035, D039-D040, D043	f	f
RCRA-Listed Industrial Chemicals and Hazardous Constituent			
Benzene	D018	0.14[e]	10[e]
Bromobenzyl cyanide	P030	Cyanides (total): 1.2 Cyanides (amenable): 0.86	Cyanides (total): 590 Cyanides (amenable): 30
Carbon tetrachloride	D019	0.057[e]	6.0[e]
Chloroform	D022	0.046[e]	6.0[e]
Cyanogen chloride	P033	CHOXD; WETOX; or CMBST	CHOXD; WETOX; or CMBST
Hydrogen cyanide	P063	Cyanides (total): 1.2 Cyanides (amenable): 0.86	Cyanides (total): 590 Cyanides (amenable): 30
Phosgene	P095	CMBST; or (WETOX or CHOXD) followed by CARBN	CMBST

[a] Treatment standard can be either a maximum concentration, a specific technology, or both. Where more than one standard is listed—separated by a colon—any one of the listed standards can be used. Where more than one technology standard is listed—separated by the words "followed by" —all the technology standards must be used in the order specified.
[b] Wastewater is defined as a waste that contains less than 1 percent by weight total organic carbon and less than 1 percent by weight total suspended solids (40 CFR 268.2[f]).
[c] Nonwastewater is any waste that does not meet the definition of a wastewater (40 CFR 268.2[d]).
[d] The technology-based standards included under each technology code are specified in Table 4-4.
[e] In addition, every RCRA hazardous constituent present must also meet its concentration limit.
[f] Standards are listed below under the individual RCRA hazardous constituent.
[g] The specific standard depends upon the initial mercury concentration and whether organics are present. The applicable standard is IMERC, RMERC, or a maximum concentration ranging from 0.025 to 0.20 mg/l TCLP.

CFR – Code of Federal Regulations
NA – Not applicable
TCLP – RCRA toxicity characteristic leaching procedure (40 CFR 261.24)

Source: 40 CFR 268.40 and 268.48

Table 4-4. RCRA Technology Codes and Description of Technology-Based Standards

Technology Code	Description of Technology-Based Standards
CARBN	Carbon adsorption (granulated or powdered) of non-metallic inorganics, organo-metallics, and/or organic constituents, operated such that a surrogate compound or indicator parameter has not undergone breakthrough (e.g., Total Organic Carbon [TOC] can often be used as an indicator parameter for the adsorption of many organic constituents that cannot be directly analyzed in wastewater residues). Breakthrough occurs when the carbon has become saturated with the constituent (or indicator parameter) and substantial change in adsorption rate associated with that constituent occurs.
CHOXD	Chemical or electrolytic oxidation utilizing the following oxidation reagents (or waste reagents) or combinations of reagents: (1) hypochlorite (e.g., bleach); (2) chlorine; (3) chlorine dioxide; (4) ozone or UV (ultraviolet light) assisted ozone; (5) peroxides; (6) persulfates; (7) perchlorates; (8) permanganates; and/or (9) other oxidizing reagents of equivalent efficiency, performed in units operated such that a surrogate compound or indicator parameter has been substantially reduced in concentration in the residuals (e.g., TOC can often be used as an indicator parameter for the oxidation of many organic constituents that cannot be directly analyzed in wastewater residues). Chemical oxidation specifically includes what is commonly referred to as alkaline chlorination.
CMBST	High-temperature organic destruction technologies, such as combustion in incinerators, boilers, or industrial furnaces operated in accordance with the applicable requirements of 40 CFR part 264, subpart O, or 40 CFR part 265, subpart O, or 40 CFR 266, subpart H, and in other units operated in accordance with applicable technical operating requirements; and certain non-combustive technologies, such as the Catalytic Extraction Process.
DEACT	Deactivation to remove the hazardous characteristics of a waste due to its ignitability, corrosivity, and/or reactivity.
IMERC	Incineration of waste containing organics and mercury in units operated in accordance with the technical operating requirements of 40 CFR 264 subpart O and 265 subpart O. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per RCRA waste code with consideration of any applicable subcategories (e.g., High or Low Mercury Subcategories).
POLYM	Formation of complex high-molecular weight solids through polymerization of monomers in high-TOC ignitable (D001) nonwastewaters, which are chemical components in the manufacture of plastics.
RMERC	Retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (1) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (2) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (3) a state permit that establishes emission limitations (within meaning of section 302 of the Clean Air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per RCRA waste code with consideration of any applicable subcategories (e.g., High or Low Mercury Subcategories).
RORGS	Recovery of organics utilizing one or more of the following technologies: (1) distillation; (2) thin film evaporation; (3) steam stripping; (4) carbon adsorption; (5) critical fluid extraction; (6) liquid-liquid extraction; (7) precipitation/ crystallization (including freeze crystallization); or (8) chemical phase separation techniques (i.e., addition of acids, bases, demulsifiers, or similar chemicals); Note: this does not preclude the use of other physical phase separation techniques such as decantation, filtration (including ultrafiltration), and centrifugation, when used in conjunction with the above-listed recovery technologies.
WETOX	Wet air oxidation performed in units operated such that a surrogate compound or indicator parameter has been substantially reduced in concentration in the residuals (e.g., TOC can often be used as an indicator para meter for the oxidation of many organic constituents that cannot be directly analyzed in wastewater residues).

Source: 40 CFR 268.42 Table 1

4.6.2 Municipal Solid Waste Landfill Requirements

Various nonhazardous solid wastes, such as trash and construction debris, would be generated from the use of the transportable treatment systems. Some or all of such waste generated at a specific site would be disposed of in a municipal solid waste landfill.

Subtitle D of RCRA establishes a framework for federal, state, and local cooperation in controlling the management of nonhazardous solid waste. Development, implementation, and enforcement of regulations for municipal solid waste landfills are carried out primarily at the state and local level. State regulations can, and do, vary widely in the requirements they place on municipal solid waste landfills, especially in regard to how different types of municipal solid waste are managed. RCRA Subtitle D regulations promulgated under 40 CFR 258 establish minimum national criteria that all municipal solid waste landfills must meet. These minimum national criteria have been established to protect human health and the environment.

As defined under RCRA, the term solid waste includes solid, liquid, semi-solid, or contained gaseous material that is discarded. Under 40 CFR 258, municipal solid waste landfills can receive household solid waste as well as other types of nonhazardous solid waste such as commercial solid waste (i.e., nonhazardous solid waste from nonmanufacturing activities), nonhazardous sludge, and industrial solid waste (i.e., nonhazardous solid waste from manufacturing and industrial processes).

The Subtitle D regulations under 40 CFR 258 define standards for the management of municipal solid waste landfills and specify minimum requirements for site selection, design, operation, groundwater monitoring, corrective action, financial assurance, and closure and post-closure care. State programs must incorporate requirements at least as stringent as the federal Subtitle D requirements. RCRA requires that each state develop a permit program that ensures that the municipal solid waste landfills within its jurisdiction comply with the Subtitle D requirements. These state permit programs must be approved by USEPA. Many state programs define various classes of municipal solid waste landfills—such as debris landfills, restricted waste landfills, special waste landfills, and industrial solid waste landfills—and impose more stringent requirements on certain classes of landfills.

4.6.3 Municipal Solid Waste Incinerator Requirements

Depending on local practices and regulations, some nonhazardous solid waste, such as trash, generated from the use of transportable treatment systems could be sent to a municipal solid waste incinerator for disposal. These facilities are regulated primarily under the Clean Air Act (see Section 4.1) and corresponding state laws.

In addition to the requirements discussed in Section 4.1, municipal solid waste incinerators are subject to New Source Performance Standards (under 40 CFR 60 Subparts C, Ca, E, and/or Ea) if they have a capacity of at least 50 tons per day and are constructed or modified after the effective date of the regulations—17 August 1971 for ≥50 ton per day facilities and

20 December 1989 for certain ≥250 ton per day facilities. The NSPS requirements place limits on particulate emission rates from ≥50 ton per day facilities and on particulate, sulfur dioxide, hydrogen chloride, nitrogen oxide, dioxin/furan, and carbon monoxide emission rates from ≥250 ton per day facilities. The latter facilities must also comply with specified operating requirements. All these regulated facilities must comply with performance and compliance testing requirements.

4.6.4 Wastewater Treatment Facility Requirements

The use of transportable treatment systems would generate various types of wastewaters, including rinse waters, condensates, and sanitary wastes. Wastewaters that are a hazardous waste and/or that are associated with chemical agent (see Section 3.1.10) would be put into containers and sent to a hazardous waste TSDF. Requirements that would apply at a hazardous waste TSDF are discussed above. All other wastewaters would be discharged to sanitary sewer systems or collected for transport to and subsequent treatment at a wastewater treatment facility.

Operations that discharge wastewater to publicly owned wastewater treatment facilities are subject to pretreatment requirements mandated under the federal Clean Water Act (see general pretreatment regulations in CFR 40, Subchapter N, Part 403). Discharges to surface waters from wastewater treatment facilities are regulated under the Clean Water Act's National Pollutant Discharge Elimination System (see CFR 40, Subchapter D, parts 122 and 125). Under this system, permits are required before a discharge can occur. These permits limit the amount and types of specific pollutants that can be discharged into surface waters.

4.6.5 Recycling Facility Requirements

Some wastes generated from the use of transportable treatment systems would be sent to recycling facilities for treatment and eventual recycling. These wastes includes spent oil and lubricants, spent coolant/chiller fluids, and various metal wastes such as decontaminated containers, munition casings, and metal fragments.

Recycling facilities are generally not regulated under specific waste management regulations, but are instead regulated under other more general environmental laws and regulations, primarily the Clean Air Act, the Clean Water Act, and corresponding state laws and regulations. These laws and regulations are discussed throughout Section 4. Used oil is, however, subject to specific waste management standards under 40 CFR 279, as well as to various other state and local requirements.

The used oil management regulations include standards for used oil processors and re-refiners and for used oil transporters. The standards for used oil processors and re-refiners contain design and operating requirements for the units (e.g., tanks and containers) that may be used to store or process used oil. This standard also includes requirements for preparedness

and prevention, contingency plans and emergency procedures, analysis plans, tracking of used oil shipments, operating records and reporting, and management of residues generated from used oil storage, processing, or re-refining.

4.6.6 Army Regulations

Various Army regulations apply to waste management. The principal regulations that would apply to treating CWM in a transportable treatment system and to managing the waste generated in treating this CWM are as follows: Army Regulation (AR) 50-6 (Nuclear and Chemical Weapons and Materiel, Chemical Surety), AR 385-61 (The Army Chemical Agent Safety Program), and AR 200-1 (Environmental Protection and Enhancement). The discussion below focuses only on the provisions of these regulations most relevant to treating the CWM in a transportable treatment system and to managing the waste generated by this treatment.

4.6.6.1 AR 50-6 Nuclear and Chemical Weapons and Material, Chemical Surety

AR 50-6 prescribes policies, procedures, and responsibilities for the Army chemical surety program. Chapter 10 of AR 50-6 delineates the specific provisions of the chemical surety program that apply to recovered chemical warfare material.

AR 50-6 defines *recovered chemical warfare material* as "chemical agent material and/or associated equipment and surrounding contaminated media discovered either by chance or during deliberate real estate recovery/restoration operations that was previously disposed of as waste." Chemical agent material is defined as "a quantity of chemical agent, or substance or material contaminated with chemical agent." Industrial chemicals are specifically excluded from this definition.

AR 50-6 classifies recovered chemical warfare material as a hazardous waste and mandates that it be managed in compliance with applicable environmental laws and regulations, such as RCRA and CERCLA. With regard to safety, the recovered chemical warfare material is to be managed in accordance with AR 385-61 and Department of the Army Pamphlet (DA PAM) 385-61. Other Army safety and security regulations can also apply.

Emergency on-site destruction of chemical munitions may be considered as an option when necessary to reduce risk. Non-emergency on-site destruction may also be considered as an option, subject to CERCLA or RCRA requirements and other applicable laws and regulations.

4.6.6.2 AR 385-61 The Army Chemical Agent Safety Program

AR 385-61 establishes requirements for the Army Chemical Agent Safety Program. It prescribes safety policy, responsibilities, and procedures for operations involving chemical agents and associated weapons systems. DA PAM 385-61 (*Toxic Chemical Agent Safety Standards*) specifies the minimum safety criteria and standards to be met in the processing, handling, storage, transportation, disposal, and decontamination of chemical agents.

AR 385-61 indicates that decontamination and/or disposal of hazardous waste containing chemical agent must comply with federal, state, and local laws and regulations. It defines

decontamination as "the process of decreasing the amount of chemical agent on any person, object, or area by absorbing, neutralizing, destroying, ventilating, or removing chemical agents to the extent necessary to preclude the occurrence of foreseeable adverse health effects."

DA PAM 385-61 explains the minimum safety criteria and standards for use in storing, transporting, decontaminating, and disposing of chemical agents. It defines Army safety guidelines for different levels of surface decontamination of items or materials having a solid physical state that have come into contact with liquid chemical agent; this includes the level of decontamination required before an item or material having a solid physical state can be released from government control. These safety guidelines do not apply to liquids, such as neutralents and rinse waters generated from treating CWM in a transportable treatment system.

Section 5.1 of DA PAM 385-61 designates three levels of decontamination. For the purposes of this environmental impact statement, these decontamination levels are referred to as *contaminated*, *controlled handling*, and *no restrictions*.

Contaminated material is material that has been partly decontaminated, but must still be handled using protective clothing and equipment as if chemical agent could be present.

Controlled handling material is material known or designated to be at a decontamination level requiring that some precautions still be used for handling. Material designated controlled handling can only be released from U.S. Government control if certain conditions have been met (DA PAM 385-61, Section 5.1.e[4][a]). If the material to be released is to be disposed of by burial, it can only be sent to a hazardous waste landfill approved by the USEPA or a state under the provisions of RCRA Subtitle C (DA PAM 385-61, Section 5.2.C). If the material to be released is incinerated, this must be done using a USEPA- or state-approved permitted facility, appropriate engineering controls, and continuous monitoring (DA PAM 385-61, Section 5.2.F). *Controlled handling* does not mean that chemical agent is present in or on the material. It only means that, to ensure safety, additional decontamination procedures must be carried out before the material can be designated at the *no restrictions* decontamination level and handled without taking any precautions.

Controlled handling material—such as the decontaminated waste with a solid physical state generated from treating chemical agent-filled CWM in a transportable treatment system—that is sent to a permitted commercial hazardous waste TSDF would be considered to be under government control because both the transporter and the TSDF would be acting as agents for the government.

No restrictions material is material that has been decontaminated completely of chemical agent in accordance with DA PAM 385-61 Section 5.1.c(3). Such material can be handled without taking any precautions and can be released from U.S. Government control without restriction in accordance with applicable federal, state, and local regulations.

4.6.6.3 AR 200-1 Environmental Protection and Enhancement

AR 200-1 prescribes Army responsibilities, policies, and procedures for preserving, protecting, and restoring the quality of the environment. The regulation provides an overview of environmental programs and requirements applicable to Army activities. It also supplements federal, state, and local environmental laws and integrates pollution prevention, natural and cultural resources, and the National Environmental Policy Act into the Army Environmental Program.

Among its provisions, AR 200-1 defines army policy for managing hazardous and nonhazardous solid waste. It requires compliance with all legally applicable and appropriate federal, state, and local requirements for generating, transporting, treating, storing, and disposing of hazardous and nonhazardous solid waste, including the terms and conditions of federal and state permits. AR 200-1 also indicates that disposal of chemical warfare agents and ammunition-related materials will be done in a manner that will protect the environment and in accordance with AR 50-6 and AR 385-61. It states that waste chemical warfare agents are subject to the requirements of RCRA and may meet the definition of a hazardous waste.

4.7 Utilities

Utilities needed for the deployment of the transportable chemical treatment systems include electricity, water supply, and sanitary and storm water disposal. The affected environment would be the existing infrastructure at a deployment installation or other property and would include the regional or municipal water supply and wastewater collection and treatment systems, and the local or regional electrical power utility. At most military installations and other sites, it is likely that some or all of the necessary utilities would be available although sufficient capacity might be lacking. Rural sites or sites on remote portions of existing installation could lack all utilities, requiring provision of such utilities by portable systems.

Major requirements governing drinking water supplies are the Safe Drinking Water Act and applicable state and local regulations. Wastewater treatment and discharge requirements are governed by the Clean Water Act. The Clean Water Act also applies to industrial discharges to federally owned treatment works, as well as to publicly owned treatment works. Army requirements are summarized in AR 200-1.

4.8 Traffic and Transportation

Treatment and support systems, materials, and wastes would be transported to and from treatment sites using a variety of transportation resources including federal, state, and private roads, waterways, railroads, military and public airports, and local and national airspace.

The RRS and EDS could be transported to a site by any of the transportation modes (road, rail, air, or sea). The MMD-1 and MMD-2 cannot be shipped via air transport due to size, and weight restrictions. Materials, equipment, or supplies that may be necessary to set up or operate the transportable chemical treatment and support systems would likely be transported

by truck. Many wastes generated during treatment operations would be transported by truck. Non-stockpile CWM would be transported by truck and/or military aircraft.

Various federal, state, and military regulations govern the transport of treatment systems, non-stockpile CWM, and wastes generated from CWM treatment. The remainder of this section identifies and describes those environmental laws and regulations considered most relevant to transport of CWM treatment wastes, other hazardous materials, and non-stockpile CWM items (if transported off-site). The discussion focuses on those laws and regulations that are potentially the major regulatory requirements for the NSCMP. Other laws and regulations may also apply.

4.8.1 Hazardous Materials Transportation Act Regulations

HMTA regulates the transport of hazardous materials in commerce. Hazardous materials as defined under HMTA include RCRA hazardous wastes, CERCLA hazardous substances (providing the hazardous substance is present in a quantity exceeding specified amounts), and other designated materials and substances that pose unreasonable risks in commerce. All materials, wastes, and substances that have been designated as hazardous materials subject to HMTA are listed in 49 CFR 172.101.

Regulatory responsibility for HMTA is delegated to individual states; however, HMTA places significant limitations on a state's ability to develop regulations more stringent or comprehensive than the federal HMTA regulations. If they do, USDOT may pre-exempt any state laws and regulations that unreasonably burden commerce. States may, and do, implement additional requirements in certain areas, such as provisions addressing routing restrictions, curfews, notification, and public right-to-know requirements. All states have basically adopted the HMTA regulations, with little modification, as their own state regulations. No state has been identified as having any additional provisions specific to recovered CWM.

Regulations implementing HMTA (under 49 CFR 171–179) set standards for the interstate and intrastate transport of hazardous materials (including hazardous wastes and hazardous substances) by aircraft, rail car, and watercraft vessel, as well as the interstate transport of these hazardous materials by motor vehicle. These regulations also set standards for the intrastate transport by motor vehicle of RCRA hazardous waste and CERCLA hazardous substances (but not of other hazardous materials).

HMTA regulations (under 49 CFR 171–174) establish general standards for classifying, packaging, marking, labeling, placarding, handling, and transporting hazardous materials, substances, and wastes. More detailed standards apply to certain specified classes of materials (e.g., explosives and poisonous materials). Special provisions also apply to the transport of hazardous materials that are hazardous waste. No person may offer or accept a hazardous material, substance, or waste for transport in commerce unless these HMTA requirements are met.

The HMTA regulations also establish additional standards for loading, unloading, and handling hazardous materials, substances, and wastes when transported by aircraft (49 CFR 175) or motor vehicle (49 CFR 177). More detailed standards apply to certain specified classes of materials transported by these modes (e.g., explosives and poisonous materials).

When recovered CWM or treatment wastes are transported, they may be considered to be both hazardous materials and hazardous wastes (see Section 4.6) and may also be HMTA hazardous substances if transported in quantities at or above those specified in the Appendix to 40 CFR 172.101.

For transport purposes, the recovered CWM is classified under one of two HMTA proper shipping names/hazardous materials descriptions:

- Waste ammunition, toxic, nonexplosive, without burster or expelling charge, non-fuzed (ID Number UN2016)
- Waste ammunition, toxic with burster, expelling charge, or propelling charge (ID Numbers UN0020 and UN0021)

As a hazardous waste, transport of the recovered CWM must comply with the HMTA standards in 40 CFR 171.3. These standards deal primarily with manifest requirements and are essentially identical to RCRA manifest requirements in 40 CFR 262.20.

As a hazardous material, the shipping container and transport vehicle used for transporting recovered CWM must also be marked, labeled, and placarded as specified in 49 CFR 172.300–172.560. Furthermore, except as noted below, recovered CWM meeting the classification in the first bullet above must be packaged in non-bulk packaging (e.g., a single-round container [SRC] or another Army-approved container) that meets, at a minimum, the general packaging requirements in 49 CFR 173 Subpart B, the specific requirements in 49 CFR 173.212, and the performance requirements for packing groups I or II in 40 CFR 178. Its transport is forbidden on both commercial and military passenger-carrying aircraft, and only 220 pounds (100 kilograms) may be transported by commercial cargo aircraft. This quantity limitation does not apply to military cargo aircraft.

Recovered CWM classified as ID Numbers UN0020 and UN0021 (see above) must be packaged in non-bulk packaging that, at a minimum, meets the requirements for explosive materials in 49 CFR 173.60–173.62. However, if shipped by DoD in accordance with DoD procedures, the packaging requirement that a detonating fuze or ignition device may not be assembled in the article or contained in the same outside packaging as the article is waived. The packaging must also meet the performance requirements for packing groups I and II. Alternatively, under 49 CFR 173.7(a), hazardous materials offered for transport by, for, or to DoD may be packaged in packaging of equal or greater strength as certified by policies and procedures in AR 700-143 (Performance-Oriented Packaging of Hazardous Material, 26 September 1991).

Under 40 CFR 173.7(b), shipments of hazardous material made by or under the direction of DoD for purposes of national security are declared not to be subject to any packaging regulations under 40 CFR 173. However, military regulations for packaging would still apply.

Transport of the recovered CWM is forbidden on both commercial passenger-carrying and cargo aircraft. This prohibition does not apply to military cargo aircraft, but does apply to military passenger-carrying aircraft.

4.8.2 RCRA Transport Regulations

When recovered CWM or wastes generated by treatment of CWM is transported off the site (for either intrastate or interstate transport), it must first be prepared for transport in accordance with RCRA generator standards (40 CFR 262.30–262.33) and must then be transported in accordance with RCRA transporter standards (40 CFR 263). Off-site transport must also comply with HMTA regulations. To avoid duplication, USEPA has adopted many of the HMTA regulations as its own RCRA standards. Furthermore, USEPA has declared that if a transporter meets all applicable HMTA standards (under 49 CFR 171-179) plus RCRA requirements for obtaining a USEPA identification number and for cleaning up any hazardous waste discharge that occurs during transportation, the transporter is deemed to be in compliance with all RCRA requirements.

Under the RCRA generator standards, the recovered CWM must be packaged, labeled, and marked in accordance with HMTA regulations prior to transport, and the transport vehicle must be placarded in accordance with those regulations. The shipment must be accompanied by a manifest that both describes the waste being transported and designates one facility to receive the shipment. One, and only one, alternative facility may be designated to receive the waste in case of an emergency. All state RCRA regulations incorporate these same requirements, but some require additional information on the manifest and some require the state manifest form be used instead of the federal form.

Transporters must have a USEPA or state identification number, which can be obtained simply by notifying USEPA or the state that they are a hazardous waste transporter. In some states, the transporter must also have a separate state license, permit, or certification for hazardous waste transport (Mitretek, 1996). The license, permit, or certification is generally required for all modes of transport; however, some states require it only for motor vehicle transport.

RCRA transport standards require hazardous waste transporters to comply with the manifest system, to keep specified records, and to take immediate action, including notification of proper authorities, in the case of a release during transport. Five states (Colorado, Idaho, Kansas, New Jersey, and Rhode Island) also place restrictions on allowable transport routes and/or specifically require advance notification and approval of transport routes. The routing restrictions typically either designate certain highways (e.g., interstate or major highways) as preferred routes or prohibit transportation on certain

designated roads. Only New Jersey's requirements are specific to CWM; the other states' requirements apply to all hazardous waste.

4.8.3 State Regulations

As previously indicated, HMTA applies to the interstate and intrastate transport of hazardous wastes and hazardous substances. Most states have adopted the federal law as their state law, with limited modifications. States are not allowed to implement provisions more stringent than the federal law if they unduly burden commerce. Consequently, most state modifications pertain only to routing restrictions, curfews, notification, and public right-to-know provisions. Off-site transport of hazardous wastes and hazardous substances must be in compliance with HMTA requirements.

States also regulate the size (height, width, length), configuration (number and spacing of axles), and weight of vehicles and trailers traveling over their roads, highways, and bridges. Oversized or overweight loads require special permits and may require escorts and special routing.

4.8.4 Military Transport Regulations

This section discusses the DoD, Army, and other service regulations considered most relevant to the transport of CWM and hazardous wastes generated from its treatment. Because the Army has been given responsibility for all DoD chemical warfare-related materiel destruction, the focus is on DoD and Army regulations.

Pre-transport requirements address the preparation of materials for transport and include requirements for packaging, marking, labeling, placarding, and handling hazardous materials and for preparing manifests to accompany hazardous materials shipments. Transport requirements address the loading, unloading, and handling of hazardous materials when transported by aircraft or motor vehicle. They also establish requirements for motor vehicle and aircraft operations, for technical escort operations, and for complying with the manifest system.

4.8.4.1 AR 700-143 Performance Oriented Packing of Hazardous Materials

AR 700-143 establishes procedures for packaging hazardous materials for storage and transport.

As discussed above, hazardous materials offered for transport by, for, or to DoD must be packaged either in accordance with HMTA packaging standards under 49 CFR 173 or alternatively in packaging of equal or greater strength as certified by policies and procedures in AR 700-143. AR 700-143 addresses performance-oriented packaging (POP) and defines POP as a "type of packaging based on the ability of packaging to perform to a specified level of integrity when subjected to performance tests." AR 700-143 specifies that POP testing is to be conducted in accordance with the United Nations Orange Book (United Nations, 1995). It also recommends that the American Society of Testing Materials (ASTM) standard ASTM

D 4919-89e1 (Specifications for Testing of Hazardous Materials Packagings) be used in conjunction with the Orange Book requirements.

4.8.4.2 TM 38-250 Preparing Hazardous Materials for Military Air Shipments

Army Technical Manual 38-250 provides guidance and procedures for preparing hazardous materials for shipment aboard military aircraft.

Army Technical Manual 38-250 specifies requirements for packaging, marking, labeling, and handling hazardous materials prior to military air transport. It also delineates responsibilities and training requirements for personnel performing the above functions, as well as for those inspecting the shipment. In addition, Army Technical Manual 38-250 states that hazardous materials cannot be offered or accepted for transport, transferred, stored, or otherwise handled unless accompanied by emergency response information at all times.

Army Technical Manual 38-250 packaging, marking, labeling, and handling requirements for recovered CWM are essentially identical to HMTA requirements under 49 CFR 172 and 173, except that they provide additional detail as to what is acceptable.

4.8.4.3 AR 55-355 Defense Traffic Management Regulation

AR 55-355 prescribes policies, procedures, and responsibilities for freight and passenger traffic management within the 48 contiguous states. Much of AR 55-355 pertains to the transport of passengers, not to hazardous materials transport.

Those AR 55-355 requirements dealing with the transport of hazardous materials apply almost entirely to commercial transportation, not to military transportation. However, AR 55-355 states that when military vehicles are used to transport explosives and other hazardous materials over public highways, the transport must comply with all laws and regulations applicable to commercial carriers. All personnel involved with the preparation and shipment of hazardous materials by commercial carriers or military vehicles must also meet training requirements specified in AR 55-355.

If a commercial carrier is to be used to transport military hazardous materials, the commercial carrier must be selected in accordance with AR 55-355 requirements. The commercial carrier must also comply with all applicable federal and state laws and regulations, plus additional requirements under AR 55-355 for training, inspections, and routing and for reporting accidents, incidents, or delays.

4.8.4.4 AR 385-55 Prevention of Motor Vehicle Accidents

AR 385-55 establishes procedures for carrying out the Army motor vehicle accident prevention program as a component under the Army Safety Program.

AR 385-55 requires motor vehicles transporting hazardous materials to be marked and placarded in accordance with HMTA and Army regulations, to comply with inspection requirements under AR 385-55 before being loaded and unloaded, and to comply with all HMTA regulations under 49 CFR 171, such as those for manifesting of hazardous wastes

and for providing notifications in case of any discharge of hazardous wastes or materials. Transport must follow a preplanned route that minimizes exposure in densely populated areas. Hazardous materials must be packaged in containers meeting HMTA standards under 49 CFR 173. Other requirements—such as those for safe driving operations, vehicle safety standards, fire prevention, and convoy operations—apply to all vehicles, not just those carrying hazardous materials.

4.8.4.5 AR 95-27 Operational Procedures for Aircraft Carrying Hazardous Materials

AR 95-27 prescribes guidance and procedures for aircraft carrying hazardous materials.

AR 95-27 requires that support elements (at military and civilian airfields) be informed of the arrival or departure of aircraft carrying hazardous materials. A hazardous cargo advisory message meeting AR 95-27 requirements must be sent to all affected en route, alternate, and destination stations.

AR 95-27 also specifies procedures that apply to aircraft carrying chemical warfare agents. Necessary coordination and clearance are to be obtained before the aircraft departs. Aircraft crews and technical escorts are to be provided with protective clothing and equipment. The technical escort is to have complete jurisdiction over the cargo with regard to security safeguards, protection of personnel, and repair or disposal of containers and is to be subordinate to the aircraft commander only in matters pertaining to flight safety and operations. Shipments of chemical agents are to comply with requirements in Army Technical Manual 38-250. AR 95-27 also lists actions to be taken by the aircraft commander, aircraft crews, and technical escorts during any in-flight emergencies.

4.8.4.6 AR 95-1 Flight Regulations

AR 95-1 establishes responsibilities, procedures, and rules for Army aircraft operation and for aircrew training. Most requirements apply to all aircraft, not just to those carrying hazardous materials. However, AR 95-1 requires the pilot or copilot to wear a protective mask when carrying fuzed items filled with toxic chemicals. When carrying toxic chemicals with no arming or fuzing systems, protective masks are to be readily available but need not be worn at all times.

4.8.4.7 AR 740-32 Responsibilities for Technical Escort of Dangerous Materials

AR 740-32 delineates responsibilities for the technical escort of dangerous materials.

Technical escort involves a team of technically qualified and properly equipped personnel accompanying a shipment of dangerous materials (e.g., CWM) that require a high degree of safety and/or security during transport. AR 740-32 states that technical escorts are required for all shipments of chemical agents by aircraft and for other shipments of chemical agents when the shipment exceeds the space occupied by 100 pounds of water (1.6 cubic feet or 11.9 gallons). Technical escorts must also accompany all shipments of nerve agents, except for shipments consisting of just one gas identification set.

Technical escort personnel are responsible for ensuring the safe handling and transport of the hazardous material. They are also responsible for responding to and for neutralizing preventing, or limiting hazards, injury, or damage resulting from any accidents or incidents involving a shipment under their escort. They are also responsible for planning or performing emergency neutralization and subsequent disposal of chemical agents and munitions or other hazardous material.

4.9 Cultural Resources

Cultural resources may be defined as archaeological and historic structures in association with prehistoric and historic sites of significance derived from human habitation, and fossil evidence of previous geologic periods. Historic resources include prehistoric and historic structures, objects, and traditional cultural properties, such as areas of religious significance for Native Americans.

Federal activities that could potentially affect cultural resources must comply with various federal and state regulatory requirements enacted to protect cultural resources. The National Historic Preservation Act of 1966, as amended, is the primary federal regulation for the identification and preservation of cultural resources on DoD properties. The National Historic Preservation Act established the National Register of Historic Places, which is a national inventory of important cultural resources. The protection of federal properties eligible for or included on the National Register of Historic Places is provided for in Section 106 of the National Historic Preservation Act (Protection of Historic and Cultural Properties Regulation). Other federal statutes enacted for the protection of cultural resources and Native American rights include the Antiquities Act of 1906, the Native American Graves Protection and Repatriation Act of 1990, the American Indian Religious Freedom Act of 1978, Executive Order 13007 (Indian Sacral Sites), the Archaeological Resource Protection Act of 1979, and the Archaeological and Historic Preservation Act of 1974. Additionally, DoD agencies implement Department of Defense Directive 4710.1, Archaeological and Historic Management, and Executive Order 11593, Protection and Enhancement of the Cultural Environment. Army policies, procedures and responsibilities for meeting cultural resources compliance and management requirements are prescribed in AR 200-4, Cultural Resources Management.

The DoD is responsible for numerous natural, cultural, and Native American resources on various installations and properties across the United States. The Legacy Resource Management Program (Legacy Program) was created by the Defense Appropriations Act of 1991 to enhance the management of natural and cultural resources on DoD properties. Projects initiated under this program include state, regional, and national studies of DoD's biological, cultural, and geophysical resources. Data gathered during these projects provide valuable information on the types and locations of natural, cultural, and Native American resources located on DoD properties.

Cultural and historic resources within each state are provided protection and management through the State Historic Preservation Offices. In some states, there are also Tribal Historic Preservation Offices with a similar function. The State Historic Preservation Office is the primary point of contact for information on the location of known and potential archaeological, cultural, and historic sites that must be provided protection. All federal activities with the potential for affecting cultural and historic resources must be coordinated and approved by the State Historic Preservation Office and/or the Tribal Historic Preservation Office.

Information on the existence of cultural or historic sites can be acquired from various sources, such as the National Archaeological Data Base, the National Register of Historic Places, and the State Historic Preservation Offices. The National Archaeological Data Base is an inventory or data base containing information on existing known archaeological sites documented by State Historic Preservation Offices. The National Archaeological Data Base contains information on sites located across the United States.

4.10 Land Use

Land use includes use of land resources for (1) residential, public use, recreational, religious, and aesthetic purposes, (2) economic production (commercial, retail, industrial), or (3) natural resource protection. Land use is generally regulated on a state or local level according to zoning ordinances, growth and management plans, and development zones. Local permits may be required for siting and construction of storage, treatment, and support facilities. Land uses on military installations are often governed by integrated land use master plans. Restrictions on land use can limit the type of development. Land use types that are often subject to special protections include state and national parks, state and national forests, wildlife refuges, wilderness areas, wetlands, and conservation districts.

Many of the locations where non-stockpile CWM are anticipated to be treated would be active military installations or on formerly used defense sites no longer under DoD control. Potential sites that could be used for the treatment or storage of non-stockpile CWM could range from heavily urbanized or industrial environments to rural areas devoid of human habitation. In some cases, historical, cultural or natural resources considered to be significant could be situated in close proximity, as well as sensitive land uses, economically important uses, or residential areas. In addition, potential sites for the treatment or storage of non-stockpile CWM may not be of adequate size to accommodate the necessary treatment systems or storage facilities, or may not be of adequate size to ensure the safety of adjacent populations in the event of accidental releases.

4.11 Socioeconomic Characteristics

Socioeconomic characteristics refers to the demographic, infrastructure, and economic characteristics of a region, and its related attributes, which have the potential to be either directly or indirectly affected by temporary influxes of workers and by temporary

evacuations during CWM handling and treatment operations. Community institutions and infrastructures that could be affected would include schools, housing, and public health and safety services (i.e., fire, police, and health care). Economic characteristics that could be affected primarily include local labor resources and income.

The range of conditions that might be present at any specific deployment of the transportable chemical treatment systems could range from very rural areas to large metropolitan communities. In general, smaller communities are more vulnerable to an increase in the number of workers coming into a community than larger more diverse communities. Additionally, the vulnerability of a local community to changes in population size due to an influx of workers, depends on the strength of the economic base, the diversification of the employment sector, the number of available workers, the duration of the influx, and inter-industry linkage. Communities with a strong economic base are generally not affected by socioeconomic change as much as communities that rely solely on a single employer or employment sector.

4.12 Environmental Justice

Executive Order (EO) 12898 entitled Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, focuses federal attention on the environmental and human health conditions of minority and low-income communities and calls on agencies to make achieving environmental justice part of their mission. The Executive Order, as amended, directs federal agencies to develop an environmental justice strategy that could be used to identify and address disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority and low-income populations. In response to the Executive Order, DoD has developed an environmental justice strategy that uses the National Environmental Policy Act process as the primary mechanism to implement the provisions of the Executive Order (Department of Defense, 1995; Department of Defense Instruction 4715.9). It requires that DoD components include in process documents (environmental assessments, environmental impact statements, and records of decision) an analysis of an action's potential for disproportionately high adverse human health, economic, or environmental effects on minority and low-income populations.

A minority population is a group of people and/or community experiencing common conditions, and which consists of persons classified by the U.S. Bureau of the Census as Negro, Black, African American, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, or other nonwhite, based on self-classification by people according to the race with which they most closely identify. A low-income population is defined by the U.S. Bureau of the Census as a census tract with a median annual income for a family of four equal to or below the national poverty level ($16,655 in 1998; U.S. Census Bureau, 1999). Low-income populations often have limited access to health care; an inadequate, overburdened, or aged infrastructure; and a particular dependence of the community, or components of the community, for subsistence living. Often these populations are clustered together in an existing minority or disadvantaged community.

Environmental justice issues could arise as a result of deployment and use of transportable chemical treatment systems, the transport of non-stockpile CWM, or the continued storage of non-stockpile CWM. When there is a choice of sites, deployment, and operations in locations surrounded by minority or low-income populations could potentially affect these populations disproportionately.

4.13 Consultation with Native American Tribes

The Presidential Memorandum "Government-to-Government Relations with Native American Tribal Governments" (April 29, 1994) and Executive Order 13084 (May 14, 1998) "Consultation and Coordination with Indian Tribal Governments" directs each executive department to operate within a government-to-government relationship with federally recognized tribal governments, consult with tribal governments, and assess the effect of federal government plans, projects, programs, and activities on tribal resources. Consultation with Native American populations within the affected environment will depend upon site-specific issues such as population affiliation with ancestral lands, sacred sites, and cultural practices in addition to historical and cultural resources, which include locations, sites, structures, and objects of significance.

4.14 Emergency Planning and Community Right-To-Know Act

Mobile treatment system operations will involve the use and treatment of a variety of hazardous chemicals. EPCRA—also known as Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA)—created requirements for informing the public about hazardous chemicals present at facilities in their community and established requirements for developing emergency response capabilities at state and local levels. (EPCRA; 42 USC 11001 et seq.)

Executive Order 12856 (3 August 1993) declared that federal agencies (including military departments) must comply with all EPCRA requirements. However, the Executive Order provides that in the interest of national security, the head of a federal agency may request an exemption from complying with any or all provisions of EPCRA for particular facilities. In addition, the Executive Order states that federal agencies are encouraged to comply with all state and local right-to-know and pollution prevention requirements to the extent such compliance is not already mandated.

EPCRA imposes requirements for establishing a local emergency planning committee for each emergency planning district in a state. Regulated facilities are to provide the following:

- A representative to the planning committee
- Information necessary for developing and implementing a local emergency plan
- Emergency notification if there is a regulated release from the facility

- Annual reports to USEPA and designated local authorities on the quantities of hazardous chemicals present at the facility and on the disposition (e.g., transfer or releases) of such hazardous chemicals.

The requirements for emergency notification are implemented under 40 CFR 355. Emergency notification is required if there is a release beyond the facility boundary of an extremely hazardous substance in excess of its designated *threshold planning quantity* or of any CERCLA hazardous substance in excess of its designated *reportable quantity*. Appendices A and B of 40 CFR 355 list over 350 substances designated as extremely hazardous substances along with their threshold planning quantities and reportable quantities.

EPCRA uses the same definition of release as CERCLA. If there is a release, notification (under 40 CFR 355.40) must include information about the substance; quantity, duration, and time of release; media into which release occurred; known or anticipated health effects; and, where appropriate, advice regarding medical attention for exposed individuals. Follow-up notices are also required.

Beginning in calendar year 1994, all federal agencies were required to comply with the provisions in sections 301-303, 304, 311-312, and 313 of EPCRA, all implementing regulations and future amendments.

EPCRA Sections 311 and 312 are the community right-to-know provisions. These sections require the submission of chemical hazard information for chemicals that exceed certain reporting thresholds. Notification of emergency authorities must be made if the hazardous chemicals present on site are greater than or equal to 10,000 pounds, or the substances are extremely hazardous substances and the amount present on site is greater than or equal to 500 pounds (or 55 gallons) or its threshold planning quantity (whichever is less). EPCRA Section 313 requires the annual submission of individual release data if the facility manufactures or processes any listed toxic chemical in excess of 25,000 pounds, or otherwise uses and listed toxic chemical in a quantity over 10,000 based on usage throughout the calendar year.

Section 5

Environmental Consequences of Normal Treatment System Operation

This section describes the possible environmental and socioeconomic consequences from the normal operation of the transportable treatment systems as described in Section 3.1. Normal operation means that site preparation, treatment system setup, treatment system and site operation, and site demobilization and closure would take place as planned and designed without any accidental releases of hazardous chemicals such as chemical agent or treatment neutralent wastes. All associated activities would also take place as planned, designed, or within regulatory limits. This includes transport of CWM, chemicals, and waste and all treatment and disposal activities at the TSDF that receives the operation wastes. The possible environmental consequences of accidental releases of hazardous substances are described in Section 6.

Transportable treatment systems could be deployed to a location on the military installation or other property where the CWM items are stored or buried or to a location elsewhere. Under the latter deployment situation, CWM items would be transported by truck and/or aircraft from the storage or burial site to the treatment system location.

The environmental impacts are described below for the life-cycle stages of a site. These stages are treatment site preparation and treatment system setup (Section 5.2), normal treatment site operation (Section 5.3), and treatment system closure and demobilization and site closure (Section 5.4). Section 5.5 describes the possible impacts of transporting CWM items by truck and/or by aircraft to a distant treatment location under normal conditions. The analysis is restricted to treating and processing only the non-stockpile CWM items described in Section 1.5.

Activities that take place at non-stockpile CWM burial and storage sites prior to treating the items in a transportable treatment system are described in Section 1.9. These environmental management activities are the responsibility of other DoD organizations (see Section 1.8) and are necessary to ensure public health and safety at those locations. These activities are independent of whether the proposed transportable treatment systems are deployed as proposed by the Army (Preferred Alternative; Section 3.1) or the Army decides to find and develop a different method or technology to treat non-stockpile CWM (No-Action Alternative; Section 3.2). These activities are not under the control of the NSCMP; are independent of the NSCMP activities; are subject to environmental review and analysis under RCRA, CERCLA, and other statutes and regulations; and require public comment and input in the decision-making process. Therefore, the environmental impacts of these activities are not covered in this programmatic environmental impact statement since they will be considered independently as part of decisions made for these other programs.

The environmental impacts discussed in this section are programmatic in nature, as discussed in Section 1.3. If the Army decides to implement the preferred alternative and make the treatment systems available for deployment to specific locations, site-specific impact analyses would be conducted in the future when a decision is to be made about treating and processing non-stockpile CWM buried or stored at a specific location.

5.1 Treatment System Deployment Scenarios Analyzed

The type of transportable treatment systems that would be deployed to a site would depend on the types of non-stockpile CWM items that must be processed and treated. Section 3.1.2 has described how all sites are not the same and that sites could have several types of CWM. Table 3-1 in Section 3 shows that more than one type of treatment systems could be deployed to a site if several types of items are present. If more than one type of system is required, they could be deployed sequentially or at the same time.

Three treatment system deployment scenarios are used for analysis in the following sections to bound the environmental impacts at a treatment site. Scenarios 2 and 3 assume that all treatment systems indicated for the scenario are at the treatment site at the same time.

Scenario	Treatment Systems at the Site
1	RRS
2	RRS, MMD-2*
3	RRS, MMD-1, MMD-2[a]

*With bulk item accessing equipment

An EDS could also be present at the sites in scenarios 2 and 3 if an explosively configured item is determined to be unsafe to handle and move to be processed in the MMD -2. This would likely be an infrequent occurrence. The occasional presence of an EDS would not add significantly to the resource requirements at the site. A scenario for a deployment of an EDS alone is not considered because the impacts would likely be similar to those at a site with an RRS.

The Army has not yet decided how many of each type of transportable treatment system would be built and operated if the preferred alternative is selected. It is possible that there could be more than one of each type. Therefore, for purposes of analysis in this environmental impact statement only, it has been assumed that the following number of treatment systems could be operating in any single year:

Treatment System	Number
RRS	2
MMD-1	2
MMD-2	3
EDS	2

5.2 Treatment Site Preparation and Treatment System Setup

Once a specific treatment system site has been selected and all necessary approvals and permits have been received, the site would be prepared for use. When the site is ready, the treatment system or systems would be brought to the site and set up for use.

Preparations needed at a specific site would depend on its characteristics and the support infrastructure already available. Specific activities needed could include grading and other physical alterations to the site, altering existing buildings, installing foundations and footers, installing or modifying utility systems, and constructing or modifying roadways and parking areas. Site preparation is described in Section 3.1.3.

The treatment systems would be transported to the site by the most appropriate mode. The components would be set up and connected to utilities. Treatment system setup is described in Section 3.1.4.

5.2.1 Air Quality

Treatment site preparation and treatment system setup would generate various air emissions at the site. The types and quantities of emissions generated would be site-specific and would depend on a variety of factors at the site. Major factors affecting emissions would include the number and types of treatment systems to be deployed to the site; the specific site preparation and setup activities conducted at the site; the specific equipment and vehicles used; the time required for site preparation and setup; the physical characteristics of the site; federal, state, and local air quality regulations applicable at the site; and the air pollution controls and mitigating measures that would be implemented at the site.

Air emissions generated would include criteria pollutants released by the operation of vehicles and equipment involved in site preparation and setup activities and in the transport of personnel, equipment, materials, and construction-generated wastes. Fugitive dust would be released by vehicles, equipment, and activities that disturb the ground surface, as well as by some other construction-related activities. HAPs could also be released by vehicles, equipment, and various construction-related activities such as painting and solvent cleaning.

Air quality impacts from these emissions would be very site-specific. Major factors that would affect impacts include (1) the specific types and quantities of emissions that would be released, (2) existing air quality levels in the area, including the area's attainment status, (3) applicable federal, state, and local air quality regulations, including any state and local regulations that are in addition to, or more stringent than, the federal requirements, and (4) other local site-specific issues.

5.2.1.1 Potential Air Emission Sources

Air emissions could be emitted during site preparation and setup by the following types of sources: fugitive dust-generating activities, diesel-powered generators, mobile sources such as vehicles and construction equipment, and miscellaneous construction activities.

Fugitive Dust-Generating Activities. Various site setup and preparation activities would generate particulates in the form of fugitive dust. Sources of fugitive dust would include any activities that physically disturb the ground surface at the site, such as any grading, clearing of vegetation, and excavations for any footings required at a specific site. Cleared areas could also become a source of wind-blown dust, as could any debris and spoil piles produced by construction activities. Fugitive dust could also be generated in loading debris and spoils into vehicles for transport to disposal locations. Personal vehicles, trucks, and heavy equipment would also generate fugitive dust when traveling over paved and unpaved roads. Fugitive dust could also be generated if site setup included any modifications to existing buildings at the site.

The amount of fugitive dust emissions generated would be very site-specific and would depend upon such factors as the amount of land disturbed, the specific activities conducted at the site and the timeframe over which they are conducted, the number and types of vehicles and other mobile equipment used at the site, the vehicle-miles traveled on paved and unpaved roads, the dust suppression and other mitigating measures used at the site, and such local factors as wind speed and the silt and moisture content of site soils.

State and local regulations and military installation requirements could dictate controls, such as covering trucks hauling dirt, sand, soil, or other loose material; applying water or other dust suppressants; or restricting activities on days with unfavorable meteorological conditions. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

Diesel-Powered Generators. Diesel-powered generators could be used to generate electrical power during site setup and preparation at various sites, either as the primary source of power or as an emergency backup (see Section 5.2.7.3). When used, diesel-powered generators would emit such criteria pollutants as nitrogen oxides, sulfur oxides, carbon monoxide, hydrocarbons, and particulate matter. Diesel-powered generators would also emit small quantities of some HAPs such as acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde, naphthalene, propylene, toluene, and xylenes (U.S. Environmental Protection Agency, 1996a). Emission quantities would be site-specific, would depend upon such factors as the hours of operation and the amount of power generated, and are discussed in Section 5.3.1.1. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

Mobile Sources. Mobile sources of emissions would include trucks, personal vehicles, and heavy construction equipment used at the site. Trucks would be used to transport the construction equipment and supplies, and possibly the treatment system itself, to the site and to transport construction-related wastes from the site. Personal vehicles would be used to transport workers to and from the site. The construction equipment used would depend on

the specific construction activities carried out and could include graders, bulldozers, forklifts, and similar equipment.

The mobile sources would release criteria pollutants. Emission quantities would be site specific and would depend upon such factors as the vehicle-miles traveled by the cars and trucks and the total number of hours that heavy-duty construction equipment is operated.

Miscellaneous Sources. Various other construction-related activities, such as painting, solvent cleaning, and equipment maintenance, would produce small amounts of solvent-based emissions that could include both HAPs and other volatile organic compounds. These emissions would be extremely site-specific and would depend on the activities conducted, the materials used, and the timeframe over which they are used. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

5.2.1.2 Air Quality Impacts

Air quality impacts from site preparation and treatment system setup would be extremely site specific and would depend upon such factors as the specific types and quantities of air pollutants emitted, existing air quality in the area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts would have to be in compliance with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented during site preparation and treatment system setup as necessary.

All necessary air quality reviews, permits, and approvals would be obtained before a transportable treatment system could be set up at a specific site. The need for additional controls and mitigating measures would be identified and implemented based on these reviews, permits, and approvals. The specific reviews, permits, and approvals necessary would also be site specific and, as discussed in Section 4.1, would depend upon such factors as the types and quantities of emissions released, existing air quality in the area, and state and local regulations that are in addition to, or more stringent than, federal requirements.

As indicated in Section 4.1, the need for certain reviews, permits, and approvals depends upon the total annual quantity of regulated pollutants emitted, or potentially emitted, by the source, which in this case is the transportable treatment system. Emissions from site preparation and treatment system setup would be just one component of the total emissions that need to be considered. Emissions from other relevant life-cycle activities, such as treatment system operation, closure, and demobilization, would also need to be considered in determining total emission quantities and the specific reviews, permits, and approvals necessary. This would be true even for the preconstruction New Source Reviews discussed in Section 4.1.2. However, certain emissions, such as those from constructing the source and those from associated mobile sources, are not considered in determining a source's potential to emit for a New Source Review or for a Title V operating permit. These emissions would,

however, be considered in making a conformity determination for a transportable treatment system to be located in a nonattainment (or maintenance) area and in meeting other state-specific requirements.

Furthermore, the need for certain reviews, permits, and approvals would also depend upon whether the transportable treatment system constituted a new source or whether it was being setup at an existing stationary source, such as a military installation, where it would be considered a modification to the source. In the former case (when the transportable treatment system would be a new source), the need for these reviews, permits, and approvals would be determined based solely on the emissions from the transportable treatment system life-cycle activities. In the latter case, the need for reviews, permits, and approvals would be determined considering the emissions from the transportable treatment system life-cycle activities in conjunction with the emissions from the existing stationary source. For example, even if the existing source did not itself constitute a major source subject to certain regulations, the incremental emissions from the transportable treatment system could be sufficient for the modified existing source to become a major source now subject to the applicable review, permit, or approval.

Air quality impacts from all life-cycle phases are addressed further in Section 5.3.1.

5.2.2 Noise

Noise would be generated by site preparation and setup activities. Noise sources could include operation of equipment during any required site preparation and setup activities including grading, the removal of trees and vegetation as part of establishment of a clear zone; transport of the materials necessary for site preparation and setup activities; transport of the transportable chemical treatment and support systems to the site; and setup of chemical treatment and support systems and erection of an environmental enclosure. The noise levels would be intermittent and would vary from hour to hour during normal work hours, depending on the site-specific activities undertaken. These sources of noise could potentially disturb nearby residents and terrestrial wildlife, the extent depending on the source of noise, the distance of potential noise receptors to the sources, and meteorological conditions.

The types of equipment that might be used could include heavy-duty trucks, graders, bulldozers, forklifts, and similar equipment. Such equipment can generate noise in the range of 67 dBA to 98 dBA at a distance of 50 feet from the source (Golden et al., 1979; U.S. Environmental Protection Agency, 1972). The level of noise could be greater if several pieces of heavy equipment are operating simultaneously. Time-averaged noise levels for major construction sites typically range from about 77 dBA to about 89 dBA for an 8-hour workday, depending on the type and pace of construction activity. The type and scope of activities that would be conducted to prepare and setup any of the treatment systems would generally be similar to that which would occur during small- to medium-scale construction projects.

In general, the increased noise during site preparation and setup activities would be short-term and of limited duration. Site preparation and setup activities would generally be limited to no more than 90 days at most sites. At non-stockpile CWM sites where major improvements are required to access roads, in order to transport the systems to the site, site preparation activities could take longer and could introduce additional sources of noise. Noise levels after normal work hours would be unaffected, since all site preparation and setup activities would be limited to normal work hours unless factors at the site require other working hours.

Noise generated at the site would dissipate as it radiates out from the source due to the phenomenon of spherical spreading of the sound waves. The noise intensity decreases inversely with the square of the distance from the source resulting in a noise-level reduction of 6 dBA for every doubling of the distance from the noise source (Hirshhorn, 1989). Other attenuating effects, due to terrain, vegetation, atmospheric effects, and obstructing structures, can reduce noise levels by an additional one dBA for every doubling of distance from the source (Schomer, 1997). These effects coupled with the likelihood that most sites would be located well away from populated areas for safety reasons would reduce the level of noise at receptor locations at a distance from the treatment site. Where noise-sensitive receptors are close to the site or the site-generated noise is greater than expected, mitigation measures may need to be employed.

The identification of acceptable locations and/or sites for the transportable chemical treatment and support systems and storage facilities could consider the potential impact of noise sources and ensure that candidate sites are not in close proximity to sensitive receptors or facilities (such as schools, retirement homes, hospitals, or other long-term health care facilities). Where operations must be sited near sensitive activities and land uses, noise abatement measures might be required. Several mitigation measures could be used to reduce the impacts of noise due to treatment and support operations. Both natural and man-made noise reduction barriers could be used. Noise reduction measures (such as using sound enclosures with sound dampening properties and mufflers) could be implemented at the sources of noise. For site preparation and setup activities, equipment and methods could be altered to reduce excessive noise.

5.2.3 Geology, Minerals, and Soils

Soils would be affected by site preparation activities such as grading, placing gravel where equipment is to be operated, constructing foundations and footers, constructing roads and parking areas, and compaction from equipment operation and placing treatment system trailers and support systems. The extent of effects on soils would be determined by the characteristics of each specific site and the mitigating measures implemented at each site. The amount of land that could be affected at a specific site could range from about 1 acre for an RRS alone (deployment scenario 1) to about 6 acres for deployment scenario 3 (RRS, MMD-1, and MMD-2).

Prime and unique farmlands and farmlands of statewide importance would be identified during the site selection process and impacts determined, as required under the Federal Agricultural Improvement and Reform Act and the Farmland Protection Act. These lands would be avoided or mitigating measures would be implemented to reduce or eliminate impacts to these resources. Mitigating measures could include removing and stockpiling topsoil and implementing special soil erosion procedures and methods.

Access to economically important subsurface minerals underlying or near the site could temporarily be restricted or eliminated during site preparation and the following operation phases. These restrictions would only be temporary for the duration of the period while site activities were ongoing. It is not likely that site preparation activities would permanently foreclose access to subsurface minerals.

5.2.4 Groundwater

It is unlikely that groundwater in the vicinity of the treatment site would be affected adversely by site preparation activities. No wells would be drilled. Placement of shallow foundations and footers and, possibly, trenching to install utilities would be the only subsurface digging activities that would take place. Site grading, if needed, could change groundwater recharge characteristics somewhat at the site. The extent of impacts, if any, would be determined by the characteristics of the specific site.

The presence of sole-source aquifers, wellhead protection areas, and source-water areas would be determined during the site-selection phase in coordination with state, local, and tribal jurisdictions. Impacts to these resources, as required under the Safe Drinking Water Act, would be determined and mitigating measures implemented if required. Mitigating measures could include special spill-response procedures or putting in place special measures to contain or control spills.

5.2.5 Ecological Environment

Effects on the ecological environment would depend on the circumstances of each specific site and the ability to select the location of the operating site so as to reduce or eliminate adverse impacts. Potential ecological impacts would be considered as part of the site-selection process. Impacts identified would be a factor in selecting the site location and in determining mitigating measures required. The amount of land that could be affected could range from about 1 acre for an RRS alone (deployment scenario 1) to about 6 acres for deployment scenario 3 (RRS, MMD-1, and MMD-2).

5.2.5.1 Upland Environment

The upland environment could be affected by clearing vegetation, grading, placing gravel, constructing roads and parking areas, constructing footings and foundations, and placing structures. The extent of these impacts would depend on the existing physical status and prior disturbance of the site selected.

5.2.5.2 Wetland and Floodplain Environment

Wetlands could be affected if the site contained wetlands within the operating area or if runoff from the site affected adjacent wetlands. Floodplains could be affected if operations were within the floodplain. Wetlands and floodplains would be considered as part of the selection process for specific sites. It is unlikely that an operating site would be selected in wetlands or on a floodplain unless site circumstances required it because other options were not acceptable.

The U.S. Army Corps of Engineers with the concurrence of the USEPA administers regulations on activities in wetlands and issues permits for these activities under the provisions of Section 404 of the Clean Water Act. If operating in wetlands cannot be avoided at a site, and a permit is issued for the operations, the permit would contain measures to mitigate the impacts. Mitigating measures could include constructing wetlands at another location to offset the loss of wetlands at the operating site or restoring the effected wetlands when the site is closed after operations are completed.

Sediment runoff from a site could also affect adjacent wetlands. Adverse effects are likely to be controlled to an acceptable level or eliminated by sediment control management measures that would be required by many states and by all military installations. State and/or installation authorities must approve a site sediment control plan before site preparation activities begin. Sediment control management measures must be installed before site preparation activities commence. Sediment control measures must be inspected and kept in proper operating condition during the entire site preparation phase.

If an operating site must be in a floodplain, the Army would comply with Executive Order 11988, Floodplain Management. This Order requires that the Army consider the impacts of the activities in a floodplain and implement measures to minimize these impacts. These considerations would be carried out as part of the site selection phase and would be implemented as part of site design and site preparation.

5.2.5.3 Aquatic Environment

Storm water runoff from the site into adjacent aquatic environments could contain some additional sediment and contaminants because of soil disturbances during site preparation, such as grading. Domestic wastewater would also be generated on site.

Sediment and Contaminants in Runoff. Sediment and contaminants in storm water runoff from the site could affect aquatic environments adjacent to the site during site-preparation activities. The increase in sediment in runoff would be site-specific but is likely to be small at any site. Adverse effects are likely to be controlled to an acceptable level or eliminated by site sediment control management measures that would be required by many states and by all military installations. State and/or installation authorities must approve a site sediment control plan before site preparation activities begin. Sediment control management measures must be installed before site preparation activities commence. Sediment control

measures must be inspected and kept in proper operating condition during the entire site preparation phase.

Storm water runoff could contain small quantities of hydrocarbon contaminants from spills of fuel, oil, or lubricants during site preparation. The amount is likely to be small, however, because the volume that could be spilled would be small and standing operating procedures would be in place to contain any spill and remove any contaminated soil from the site.

It is possible that a National Pollutant Discharge Elimination System permit issued under the provisions of the Clean Water Act also may be required if storm water runoff drains into a collecting system that discharges to surface waters. If a permit already exists for discharges from the area chosen for treatment system operation, the permit conditions may need to be reviewed to determine if the permit must modified. This review would take place before site preparation activities would begin.

Domestic Wastewater. Domestic and other uncontaminated wastewater generated during site preparation would be discharged to a wastewater treatment system, which would usually discharge its effluent to surface waters. Site wastewater could be discharged directly to a wastewater system at the site or to portable domestic waste-collection systems brought to the site. Portable systems would be discharged to an off-site wastewater treatment system. These discharges would be regulated under the National Pollutant Discharge Elimination System permit issued to the wastewater treatment facility.

5.2.5.4 Threatened and Endangered Species

Any possible effects on threatened and endangered species would be a site-specific consideration and would have to be evaluated and analyzed when a specific site is considered as a treatment location. Consideration of this issue would be part of the site selection process.

The military installation or U.S. Army Corps of Engineers would determine the actual or potential occurrence of federally and/or state-listed threatened or endangered species at or near any site under consideration for treatment system operation. This determination would be made in consultation with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service and with appropriate state agencies.

The presence of a threatened or endangered specie at a site or the potential to have an effect on a species when operating at a site would be a factor in the site selection process. If the site must be used or impacts cannot be avoided, the Army would work with federal and/or state authorities to implement appropriate mitigating measures for that particular species and site. Mitigating measures could include habitat protection or improvement at another location or restrictions on operations at the site.

Any effects on threatened and endangered species that are due only to activities during site preparation and not other phases would be short term. Site preparation would last only for 60 to 90 days.

5.2.6 Waste Management

Site preparation and treatment system setup activities would generate the following waste streams for each type of transportable treatment system: construction waste and debris, trash and similar solid waste, sanitary waste, and spent oil and lubricants (see Table 3-3 of Section 3). The environmental consequences of managing sanitary waste are discussed in Section 5.2.7.2. The environmental consequences of managing the other three waste streams are discussed below.

All three waste streams would be similar in nature to waste streams generated by most other types of small- or medium-scale construction activities. The volume and specific composition of each waste stream would depend upon such factors as the size of the area required for treatment system setup and operation; the number of personnel present and the timeframe over which they are present for site preparation and system setup; and existing site-specific conditions, such as whether necessary infrastructure is present or needs to be installed or modified and whether grading of the site and clearing of vegetation is necessary.

Construction debris and trash would be sent to permitted solid waste management facilities. Spent oils and lubricants from equipment maintenance would be sent to a waste oil recycling facility.

The specific facilities used to manage each waste stream would be determined on a site-specific basis and would depend upon the site-specific nature and composition of the waste stream. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process. The wastes would be managed in accordance with all federal, tribal, state, and local laws and regulations applicable at the treatment site and at the waste management facility. Compliance with these laws and regulations would be addressed in the site-specific analyses and documentation prepared for each site. Section 4.6 discusses the federal waste management regulations that would apply in managing the wastes at each type of facility.

On a national basis, recycling the volume of used oil that would be generated by treatment site preparation and treatment system setup activities would represent an insignificant increase in the more than 380 million gallons of all types of waste oil recycled for reuse or burned for energy recovery annually in the United States (U.S. Environmental Protection Agency, 1999a). Sending the construction waste, debris, and trash to a permitted solid waste landfill would represent an insignificant increase in the more than 116 million tons of solid waste disposed of annually in such landfills in the United States (U.S. Environmental Protection Agency, 1998b). Sending the trash and similar solid wastes to a municipal solid waste incinerator would represent an insignificant increase in the more than 36 million tons of waste burned annually in such facilities in the United States (U.S. Environmental Protection Agency, 1998b). Site-specific impacts to local waste management facilities, such as impacts

to their existing waste management capacity, would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

5.2.7 Utilities

Utilities needed for the deployment of the transportable chemical treatment systems include electricity, water supply, and sanitary wastewater disposal. At most military installations and other sites, it is likely that some or all of the necessary utilities would be available. Some sites could lack all utilities, requiring provision of such utilities by portable systems.

5.2.7.1 Water Supply

During most of the site preparation and setup phase, potable water would be needed mainly for drinking water and sanitary needs of on-site personnel. Assuming a usage factor of 25 gallons of potable water per worker, the amount of water needed per day is shown below for each of the deployment scenarios discussed in Section 5.1. The number of personnel includes up to 20 people needed for support functions, such as administrative support, security, food service, and maintenance support. The actual number of support personnel needed would vary by site and nature of deployment.

Deployment Scenario	Personnel	Estimated Water Usage (gal/day)
1	38	950
2	78	1,950
3	118	2,950

More water would be needed toward the end of the setup phase as the assembled systems were flushed and leak-tested prior to normal operations.

The impact that this level of water demand would have on an installations or local water utility would be site-specific and depend on the number of systems deployed and the capacity of the local system. At large military installations and urban sites served by water utilities with excess capacity, the impact would likely be small. At smaller military installations, sites served by water utilities with little or no excess capacity, and sites in arid regions the increased demand could cause adverse impacts on the utility and other water supply users including loss of line pressure, increased sediment entrainment due to higher flows, and increased depletion of local water sources.

Prior to deployment of the transportable chemical treatment and support systems, consultations would be made with local water authorities to determine if the local supply infrastructure could accommodate the treatment systems without causing significant adverse impacts. At sites where significant adverse impacts would occur or where a supply system is lacking, transportable potable water tanks would be used rather than establishing a new water supply system.

5.2.7.2 Wastewater Disposal

During the site preparation and setup phase, wastewater disposal requirements would be a function primarily of the number of personnel onsite. It is assumed that the amount of wastewater generated would be equal to the potable water usage discussed above. Where portable sanitary facilities are used, the amount of wastewater generated would be much less. More water would be needed toward the end of the setup phase as the assembled systems were flushed and leak-tested prior to normal operations.

Where available, wastewater would be discharged through existing sanitary or industrial sewer lines to the local wastewater treatment plant. If no sewer lines were available, then wastewater would be containerized and transported to a wastewater treatment facility for disposal.

The impact that this level of wastewater flow would have on an installations or local water utility would be site-specific and depend on the number of systems deployed and the capacity of the local system. At large military installations and urban sites served by wastewater treatment facilities with excess capacity, the impact would likely be small. However, local impacts could occur if local sewer lines did not have the capacity to handle the flow. At smaller military installations and sites served by wastewater systems with little or no excess capacity, the increased demand could cause adverse impacts on the utility and other sewer system users.

Prior to deployment of the transportable chemical treatment and support systems, consultations would be made with local wastewater authorities to determine if the local wastewater disposal infrastructure could accommodate the treatment systems without causing significant adverse impacts. At sites where significant adverse impacts would occur or where a wastewater system is lacking, wastewater would be containerized and transported to a wastewater treatment facility for disposal rather than establishing a new wastewater treatment and disposal system.

5.2.7.3 Electric Utilities

During the site preparation phase, electric power requirements would be similar to that of a small- to moderate-scale construction project. More power would be needed during the setup phase as the treatment and support systems were powered up and tested prior to normal operations. Full power requirements for the three deployment scenarios selected for this analysis (see Section 5.1) are shown below.

Deployment Scenario	Power Requirements kW (continuous)
1	65
2	1,400
3	1,880

Local sources of electrical power would be used, if available. Some sites may require upgrades to local transmission lines or transformer stations or installation of new lines.

Where local power was unavailable or insufficient to meet system requirements, an on-site electrical generating system would be required.

Where local power would be used, the impact on the utility and its users would be site-specific and depend on the number of systems deployed and the capacity of the local power system. At large military installations and urban sites served by an electric utility and line infrastructure with sufficient capacity, the impact would likely be small. At sites served by small electric utilities or lower capacity transmission infrastructures, the impacts on the utility and other users could be significant and include line voltage drops, degradation of line power quality, and system failures.

Prior to deployment of the transportable chemical treatment and support systems, consultations would be made with local electrical utility authorities to determine if the local power system infrastructure could accommodate the treatment systems without causing significant adverse impacts. Where necessary and feasible, upgrades would be made to the local power supply infrastructure to accommodate system requirements. At sites where significant adverse impacts would occur or where an adequate power supply system is lacking, transportable on-site diesel power generators would be used.

5.2.8 Traffic and Transportation

The principal transportation infrastructure used during site preparation and system setup would be roads and highways for transporting (1) construction equipment, materials, and supplies, (2) site preparation and setup personnel, (3) the transportable chemical treatment and support systems, and (4) solid and hazardous waste materials from site preparation and system setup to approved disposal, treatment, or recycling facilities. In addition to roadways, sea, or rail modes of transport could be used to bring the transportable chemical treatment systems and support systems to a site. The RRS and EDS are capable of being transported by military aircraft.

The impacts to local traffic and transportation systems would be site-specific and vary by local conditions and the characteristics of the actual deployment. However, potential impacts are described below in general terms as to types and general consequences.

Potential impacts to traffic and transportation due to site preparation and setup activities would include increases in truck and automobile traffic on public roads and highways near the treatment site, increased congestion, noise, and increased risk of traffic accidents. If new access roads or modifications to existing roads were necessary to bring in the transportable chemical treatment and support systems or to facilitate movement of non-stockpile CWM from a discovery site to the treatment site, traffic disruption could occur.

5.2.8.1 Site Preparation

Site preparation activities could involve ground-clearing, cutting, filling and grading operations, construction of foundation pads, spreading of gravel, and construction of

perimeter fencing. Construction of one or more environmental enclosures to contain the main operations trailers might also be needed. These activities would generally require transport of construction equipment, workers, and materials to the treatment site and removal of debris and other wastes from the site to treatment, disposal, or recycling facilities, resulting in additional truck traffic on local roads and highways near the treatment site and other facilities.

The amount of additional truck traffic generated would depend on site-specific factors, including the size of the area needed for the treatment systems, the nature of the site, the amount and type of vegetation to be removed, the type and amount of construction equipment used, and the system deployment scenario. The level of traffic generated would likely be similar to that generated by a small- to moderate-scale construction project.

At relatively small, level sites with little vegetation, the amount of site preparation could be very limited resulting in very little additional truck traffic on local roads. At large deployments or difficult sites requiring extensive site preparation, additional truck traffic could be significant with moderate impacts to local traffic and transportation facilities including increased congestion, noise, increased risk of transportation accidents, and increased wear on road surfaces.

In addition, some sites may require construction of new or modification of existing on-site or public roads or other transportation facilities, such as helicopter landing areas. These kinds of construction activities could have additional impacts on local traffic and transportation systems. Construction of new transportation facilities or modifications to existing facilities would be coordinated with state, tribal, and local transportation official (when necessary) and with responsible site authorities to minimize potential adverse impacts to existing traffic patterns and to ensure traffic safety.

Worker commuting during site preparation and setup would also generate some additional traffic in the vicinity of the site. However, site preparation personnel would be local workers and would not likely add to the overall level of commuter traffic in the area.

5.2.8.2 Treatment System Setup

The chemical treatment and support systems would be transported to the site by the most appropriate mode of transport. The RRS and EDS are capable of being transported by all modes of transportation (that is, by road, rail, air, and water). The MMD systems and other support systems are capable of being transported to a site by land (that is, by rail or road) and by water. If the transportable treatment and support systems are transported via air, water, or rail, they would likely be brought from the airport, port, or railhead to the treatment site location by truck transport.

The primary components of the transportable chemical treatment systems would be enclosed in trailers of various sizes that can be transported by truck. However, some of the trailers would be larger than standard trailers or may exceed the weight limits for certain highways and roads, requiring special-use permits in certain states. Careful route planning for the transport of the

systems would be required in order to ensure that the movement of the systems do not exceed weight restrictions and cause damage to existing highways and roads. Reviews and evaluations would be performed to ensure that roadbeds and bridges could support the weight of the transportable chemical treatment and support systems. Alternative routes would be reviewed in order to minimize any needed upgrades of roads and bridges that may be required.

The estimated numbers of truck trips needed to transport the transportable chemical treatment systems to a site are shown in the table below.

System	Estimated Number of Truck Loads	Estimated Number of Truck Trips*
RRS	6	12
MMD-1	15	30
MMD-2	20	40
EDS	3	6

* Includes return trips of tractors once trailers are transported to a site.

Under the scenarios discussed in Section 5.1, the number of truck trips generated by the transport of the transportable chemical treatment and support systems to a site could range between about 12 and 82. The movement of the transportable chemical treatment and support systems to a site could occur over a period of time ranging from a few days to a few weeks. The impact of such a movement on local traffic patterns would depend on local road and traffic conditions near the site. It is possible that such a movement could cause disruption of traffic, especially where severe congestion exists or in areas that do not normally experience significant truck traffic. However, because of the limited duration of the movement, no lasting impacts would likely occur.

Personnel for setting up the transportable chemical treatment and support systems would be provided by the operations contractor and would likely come from outside the area near the treatment site. Therefore, commuting by the setup personnel would add to local traffic volumes. The number of personnel needed to set up the transportable chemical treatment and support systems under the scenarios described in Section 5.1 are presented in the table below. The number of personnel includes up to 20 people needed for support functions, such as administrative support, security, food service, and maintenance support. These support personnel would likely be local residents. The actual number of support personnel needed would vary by site and nature of deployment.

Scenario	Personnel	Commuter Trips Per Day
1	38	76
2	78	156
3	118	236

If the non-resident personnel are not housed on-site and each person commutes by private automobile each day, between 38 and 118 addition vehicle trips could be added to local traffic each morning and afternoon for up to 90 days. At the low end (Scenario 1), no impacts are likely. At the upper end (Scenario 3), the additional traffic could have some adverse effects on local traffic, especially near entrances to the military installation or other property. Whether or not this has a significant impact on local traffic patterns would depend on the existing traffic conditions near the site and would be considered in site-specific analyses.

If the non-resident personnel were housed on site, up to 20 vehicle trips each morning and afternoon would still be added to traffic near the site as local support personnel commuted to the site. This amount of traffic would likely have no significant impact on local traffic.

Mitigation measures for reducing potential impacts to transportation resources, particularly those associated with impacts to roads and highways would include scheduling of shipments to avoid disruptions to local traffic, avoiding of roads and highways that are congested, scheduling of work hours to avoid peak commuting hours, making road improvements, and compensating for improvements to local traffic safety measures (for example, traffic signals and signs) and personnel, when necessary.

5.2.9 Cultural Resources

Cultural and historical resources, archeological sites, and Native American lands and religious areas could either be directly or indirectly affected by on-site and off-site activities. Specific issues and concerns associated with the transportable chemical treatment and support systems include (1) potential disturbance or destruction of cultural, historic, or archeological resources, (2) potential disruption or destruction of Native American religious areas, sacred sites, rituals, and traditional hunting or fishing grounds, and (3) disturbance of previously unknown Native American gravesites.

Under the deployment scenarios discussed in Section 5.1, the amount of land area that could be directly affected by deployment of transportable chemical treatment and support systems would range from about 1 acre (0.4 hectare) to about 6 acres (2.4 hectares). More land could be needed depending on the type and amount of non-stockpile CWM to be treated and the necessary site preparation activities. Also, additional land areas could be affected if a new access road or modifications to an existing access road are required, and if utilities (for example, electrical power) are extended to a site for processing and treatment operations. In addition to the land area required for system setup and operations, a controlled area would be established around the site based on the evaluation of potential accidents that could occur as

a result of non-stockpile CWM handling and treatment activities. Within the controlled area, use restrictions may be imposed and evacuation of populations from their places of residence and work could occur.

Prior to undertaking site preparation and setup activities, site-specific consultations, research, and field surveys would be performed to identify whether the siting of any of the systems or support equipment would affect historic or cultural resources. Consultations with appropriate federal agencies and State Historic Preservation Offices would be conducted. Additionally, Native American groups and representatives would be contacted to determine potential Native American concerns with the direct use of land, and land that could be indirectly impacted by non-stockpile CWM activities.

Areas where cultural resources may potentially be impacted would include all areas, sites, and structures on, under, or near the treatment site or access roads leading to the site that could be directly or indirectly affected by transport, storage, and treatment of non-stockpile CWM. Site preparation or construction activities and system setup activities could have direct and indirect impacts on culturally important sites and structures. Direct impacts could be caused by clearing, grading, excavation, and road construction activities that would have the potential to disturb underlying or adjacent cultural, historical, archeological, or Native American sites or resources. Indirect impacts could be caused by noise and vibration, emissions, or visual disturbances associated with construction activities. Such impacts could also include disturbances to the historic setting cause by the presence of the treatment system and associated activities. The nature and extent of such impacts would be site-specific and would depend on the proximity of resources or lands, the size and nature of the treatment system deployment, and the amount of site preparation required.

At large military installations, where cultural, historic, archaeological, and Native American sites, structures, artifacts, and other resources have often been well characterized and are under active management, it is likely that the siting and setup of the treatment systems could be accomplished with few if any impacts to culturally important resources. A greater potential for affecting historic and cultural resources and lands of importance to Native Americans would occur when the transportable chemical treatment and support systems, or access roads and utilities required land areas to be disturbed that were outside of existing military installation boundaries or were located on properties not under government control. Disturbance of such areas, particularly those that have not been previously disturbed or characterized, could cause irreversible physical destruction of significantly important artifacts and resources, if present. When it is necessary to utilize areas that have not been previously characterized, surveys would be performed to identify and avoid locations of significant historic and cultural resources.

As discussed in Section 3.1.2, the responsible DoD authority would conduct a site-specific analysis as input to the site-selection decision. Consultations would be undertaken with other appropriate federal, state, local, and tribal agencies to identify potentially sensitive

or important cultural sites, structures, and other resources and take appropriate measures to avoid or reduce potential impacts.

Site-specific consultations, research, and field surveys could all be necessary in order to establish the potential impacts to historic and cultural resources at sites that would be used for deployment and operation of the transportable chemical treatment and support systems. In addition, meetings and consultations with Native American groups and representatives would be conducted on issues such as the concept of sacred space, cultural values associated with certain natural resources such as sacred plants and animals, and the scope of activities that could be considered a disturbance. Impacts to Native American resources would be assessed by considering whether or not implementation of non-stockpile CWM activities has the potential to affect sites important to their belief systems and whether implementation could reduce access to traditional use of sacred areas. All interactions with federally recognized Native American groups and representatives would be conducted on a government-to-government basis beyond standard public involvement and community outreach efforts. In every case, it may not be possible to avoid adverse impacts. In the event site preparation and setup activities uncover historic or cultural resources, every effort will be made to preserve and protect these resources until a determination of their significance can be made. In the event that non-stockpile CWM activities could directly or indirectly impact Native Americans, Native American groups and representatives will be consulted during site-specific planning.

By following the appropriate state and federal protocols, disturbance to culturally important, historic, and archeological resources and Native American lands would be avoided or minimized to the greatest extent possible.

5.2.10 Land Use

The deployment of the transportable chemical treatment systems to locations with non-stockpile CWM would require a site of sufficient land area in order to conduct processing and treatment operations. Based on the deployment scenarios discussed in Section 5.1, the estimated amount of land that could be needed for setup of the chemical treatment and support systems is shown below.

Deployment Scenario	Land Area Required
1 (RRS)	1 acre (0.4 hectares)
2 (RRS, MMD-2)	4 acres (1.6 hectares)
3 (RRS, MMD-1, MMD-2)	6 acres (2.4 hectares)

The actual amount of land needed would depend on site-specific conditions, including the type and amount of CWM to be treated and the nature of the site. Additional land would be needed for storage facilities (such as an IHF) and could be needed for additional support systems. Also, more land could be needed, if as part of site preparation activities, an access

road, helicopter landing pad, or other utilities would need to be established to support receiving, processing and treatment operations.

As discussed in Section 3.1.2, a site selection process would be used to identify the actual site for setup of the transportable chemical treatment and support systems. A site-specific analysis would be conducted as input to the site-selection decision. Consultations would be undertaken with other appropriate federal, tribal, state, and local agencies to determine potential land use conflicts and appropriate measures to avoid or reduce potential land use conflicts.

The site-specific placement of transportable chemical treatment and support systems could pose a conflict with existing and adjacent land uses (such as residential, park, open space, and agricultural land uses). Impacts could include the following:

- **Conflicts with Existing Land Uses.** The nature of the operations and the need for land to deploy the systems could impact existing land uses, either at a treatment site or adjacent to it. In addition, if new access roads or landing areas were needed, existing land uses could be impacted. Compatibility of land use is generally regulated according to state, tribal, or local ordinances or land use plans. Military installations also control the use of land based on installation land use management plans. The siting of transportable chemical treatment systems or storage facilities for non-stockpile CWM would require the identification of sites for which these uses would be compatible with adjacent land uses, to the extent possible.
- **Conflicts with Sensitive Land Uses.** Land use restrictions in proximity to sensitive natural, historical, or cultural areas are often used to protect these types of land uses. Use of adjoining or adjacent lands could, directly or indirectly, affect these types of land uses.
- **Impacts on New Uses of Installation or Other Lands.** Recovery, storage, or treatment activities would preclude other uses of the land for the duration of the site preparation, treatment operations, and site closure. At closed military installations, transfer of parcels on or near recovery, storage, or treatment sites would be postponed until operations and site closures were completed.
- **Impacts on Private Ownership.** Land values, ownership rights, and use restrictions on private property could be affected by the treatment or storage of non-stockpile CWM on adjoining or adjacent lands. Temporary appropriation of land for systems and facilities or buffer zones may require compensation.

Potential land use impacts would encompass all lands used for transportable chemical treatment systems or storage facilities, and all adjacent lands that could be directly and indirectly affected by normal and accidental emissions and noise as a result of treatment and storage activities.

The site identification process for the selection of a site on a location with non-stockpile CWM would consider, to the extent practicable, siting of the transportable chemical treatment and support systems in areas away from adjacent uses that could pose a conflict. Other mitigation measures could also be used to further reduce potential conflicts. In most instances where the treatment site would be located on large active military installations, potential conflicts with existing land use would not be expected to occur as they have sufficient land areas to avoid land use conflicts and impacts. However, the likelihood for potential land use conflicts would be greater for smaller military installations and at other properties that are no longer controlled by DoD.

5.2.11 Socioeconomic Characteristics

Socioeconomic impacts include impacts to the demographic, economic, and social characteristics of communities located on or near locations that could be affected by a deployment of the transportable chemical treatment and support systems. Potential socioeconomic impacts could result from increased needs placed on existing community infrastructures and services by in-migrating workers (for example, increased need for housing) and increased demands placed on the use of emergency, hospital, and medical facilities and personnel. The types and levels of socioeconomic impacts that could be caused by non-stockpile CWM activities would be site-specific and would vary based on (1) the local demographic and geographic setting of the sites where activities would occur; (2) the number of systems deployed to a site, and (3) the duration of activities, which for non-stockpile CWM processing and treatment would predominantly be based on the types and amounts of non-stockpile CWM.

5.2.11.1 Site Preparation

During the site preparation phase, most of the work would be conducted by local contractors using local labor. Since these workers would come from the regional community surrounding the site, it is likely that that they would have little or no net impact on the socioeconomic characteristics of the area except for the benefit provided by the inflow of funds to procure local labor, materials, and services to support the site preparation activities.

5.2.11.2 Treatment System Setup

During the site setup phase, a number of workers would be brought to a site to set up the treatment and support systems and make them ready for treatment operations. The requirements for labor would vary based on the type and number of treatment systems deployed to a site. Based on the system labor requirements discussed in Section 3.1.7 and the deployment scenarios discussed in Section 5.1, the number of personnel that could be needed to set up the transportable chemical treatment and support systems are shown below.

Scenario	Number of Personnel Required for Setup
1	18
2	58
3	98

These personnel would accompany the transportable chemical treatment and support systems to the site. Many of these workers would remain to conduct the CWM treatment operations.

Site setup personnel would be contractor employees that would be assigned to the location without their families for the duration of the project. Because of the special expertise needed to operate the systems, none of the operating personnel would likely be hired locally. They would live in motels or apartments rented by the contractor in the local area. If local housing were not available, the contractor would provide temporary housing in mobile quarters moved to the area for this purpose. Because the workers would not bring their families, there would be no impacts on local schools and no impacts on the local employment market due to spouses seeking work. Workers would commute daily to the treatment site.

In addition to the operating personnel, support services could also be needed. Support staff could include administrative, security, food service (if needed), and maintenance personnel. These would likely be local personnel who already live in the region of the site. On an active military installation, security could be provided by the installation. The system-operating contractor would provide security at a non-military site. The number of support staff required would depend on the infrastructure and operating circumstances at a specific site, but could be of the order of 10-20 people.

For most sites that are on active military installations that have a large contingent of civilian and military personnel, the 18 to 98 additional setup personnel would be well within the variability of personnel assigned to the installation, and would not likely result in any significant adverse socioeconomic impacts. At most large, active military installations, services that include security, fire, medical, and emergency response capabilities would exist. Depending on the duration of setup operations, the additional personnel could provide additional indirect economic benefits to communities through personal expenditures for housing, food, and other services, while only marginally increasing the potential need for existing community institutions and services.

For non-stockpile CWM sites in rural areas (including active military installations with few personnel), the greater the number of setup personnel required, the greater the potential for adverse socioeconomic impacts to local communities, as many communities in rural areas may not have the necessary infrastructure and services to support more than a few in-migrating workers. Adverse impacts could occur to local community capabilities for responding to emergencies and in providing medical support facilities.

Mitigation measures to avoid adverse impacts on surrounding communities could require the provision of temporary housing for workers and provision for appropriate response, medical equipment, training, and potential compensation for additional public safety personnel. At locations where in-migration of personnel would potentially burden existing community services, appropriate plans would be developed prior to initiation of site preparation and setup activities. These plans would assist communities in compensating for situations when existing resources may fall short of demand and may include provisions for hiring additional police officers, fire fighters, and emergency or medical personnel during the period when activities would be conducted. The potential for adverse socioeconomic impacts would also be a factor in site selection and planning.

5.2.12 Public Health and Safety

This section addresses public health and safety consequences that could result from site preparation and treatment system setup under normal operations. Under normal operations, site preparation and treatment system setup activities would take place as planned and designed without any accidental releases of hazardous substances. In addition, waste management activities at all waste management facilities—such as solid waste management facilities, wastewater treatment facilities, and recycling facilities—would also take place as planned and designed without any accidental releases of hazardous substances. Any non-accidental releases from waste management activities, such discharges of treated wastewater following wastewater treatment, would be in accordance with permit limits. Public health and safety consequences that could result from accidental releases of hazardous substances are discussed in Section 6.

5.2.12.1 Fugitive Dust

Site preparation and treatment system setup activities that disturb the ground surface would generate fugitive dust emissions that could drift offsite. Appropriate dust suppression measures would be carried out in accordance with all applicable federal, state, local, and Army regulations to minimize the potential public health consequences from the release of fugitive dust. At some sites, the ground surface could be contaminated as the result of past activities at the site. In such cases, additional mitigating measures might be necessary. The need for mitigating measures would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

5.2.12.2 Traffic Accidents

Site preparation and treatment system setup under normal operations would generate additional truck and automobile traffic on roads in the vicinity of the treatment site. This could possibly result in a small increase in the number of traffic accidents on such roads. Under normal operations, these accidents would not release hazardous substances, such as treatment reagents. Any potential increase in traffic accidents would be site-specific and

would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

5.2.12.3 Waste Management

Under normal operations, any non-accidental releases from waste management activities would be in accordance with permit limits. Such releases would not be expected to result in any adverse public health and safety consequences. The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated by site preparation and treatment system setup activities. The appropriate DoD authority, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

5.2.12.4 Health and Safety Effects on Children

Based on the environmental consequences discussed throughout Section 5.2, children would be unlikely to be exposed to disproportionate health or safety risks from site preparation and treatment system setup under normal operations (Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks). This would be verified in the site-specific environmental analyses and documentation that would be prepared for each site.

5.2.13 Environmental Justice

A potential for disproportionate impacts to minority and low-income populations could occur at some sites. Potential impacts could include (1) lost economic opportunity, as new developments choose not to locate in areas in which non-stockpile CWM treatment and processing operations occur, (2) lower property values, (3) potential evacuation impacts, and (4) an increase in the potential for human health and safety impacts. In addition, recovery, storage, or treatment activities would preclude other uses of the land for the duration of the site preparation, treatment operations, and site closure. At closed military installations, transfer of parcels on or near recovery, storage, or treatment sites would be postponed until operations and site closures were completed. This could temporarily prevent beneficial redevelopment of the treatment site location.

The potential for disproportionately impacting minority and low-income populations as a result of the onsite processing and treatment of non-stockpile CWM would greatly depend on three specific factors: (1) the specific location of minority and low-income populations in relation to a site that would be used for non-stockpile CWM storage, processing and treatment; (2) the potential for atmospheric releases or other conditions (for example, noise) that could impact minority and low-income population areas; and (3) the duration of the non-stockpile CWM storage, processing, and treatment operations. In most situations, the impacts associated with non-stockpile CWM would not extend beyond the military installation or property on which sites would be selected for non-stockpile CWM processing and treatment operations.

Prior to selection of a site for deployment of the chemical treatment and support system, a site-specific analyses would be undertaken to determine the potential for and possible extent of any environmental justice impacts. Minority and low-income populations in the vicinity of sites that would be used for non-stockpile CWM activities would be identified and site-specific analyses performed to determine the extent to which minority and low-income populations could be disproportionately affected by site activities. Site-specific public outreach activities would both provide information and seek the input of minority and low-income populations that could be disproportionately affected. Environmental justice would be considered along with other factors in selecting a site.

Site-specific public outreach activities would be required to ensure the active and effective participation of minority and low-income populations who could bear disproportionate impacts in determining the most appropriate mitigation measures. Site-specific outreach activities would occur at the beginning of the site identification process and continue through implementation of non-stockpile CWM activities. Establishment of site-specific community advisory boards may be appropriate in some cases.

Several mitigation measures (as discussed under other topics) could be implemented to avoid, reduce, or compensate for potential adverse impacts. These mitigation measures could also result in avoiding, reducing, or compensating for adverse impacts that could be experienced by affected minority and low-income populations. Site-specific analysis will be required to determine the most appropriate forms of mitigation.

5.3 Normal Treatment Site Operation

Normal site operation would begin when site preparations are completed and the treatment and support systems have been set up. Normal operations at a treatment site means that site operations take place as planned and designed without any accidental releases of hazardous substances such as chemical agent or treatment neutralent wastes. The environmental consequences of accidental releases of hazardous substances during site operation are described in Section 6.

Before the treating and processing of CWM items would be allowed to begin, a pre-operational survey would be conducted to ensure that the treatment systems work properly (Section 3.1.5). After the Army approves the operation of the systems, CWM items would be transported to the treatment system (Section 3.1.6), and normal treatment and processing operations would begin (Sections 3.1.7 and 3.18).

Components and operation of the treatment systems are described in Section 2, and details are provided in Appendix C. Descriptions of the non-stockpile CWM items that would be processed are provided in Section 1.5 and Appendix B.

5.3.1 Air Quality

Treatment site operation would generate various air emissions at the site during normal operations. The types and quantities of emissions generated would be site-specific and would depend on a variety of factors at the site. Major factors affecting emissions would include the specific types and numbers of treatment systems deployed at the site; the specific types and quantities of CWM treated; the time required to complete treatment of the CWM; the use of any diesel-powered generators; the physical characteristics of the site; federal, state, and local air quality regulations applicable at the site; and the air pollution controls and mitigating measures that would be implemented at the site.

Air emissions generated would include criteria pollutants released by diesel-powered generators, if used, and by vehicles transporting personnel, equipment, materials, and wastes to and/or from the site. Fugitive dust would be released by vehicles and other activities that disturb the ground surface. HAPs could also be released by diesel-powered generators and various other activities such as equipment maintenance operations.

Air quality impacts from these emissions would be very site-specific. Major factors that would affect impacts include (1) the specific types and quantities of emissions that would be released, (2) existing air quality levels in the area, including the area's attainment status, (3) applicable federal, state, and local air quality regulations, including any state and local regulations that are in addition to, or more stringent than, the federal requirements, and (4) other local site-specific issues.

5.3.1.1 Potential Air Emission Sources

Air emissions could be emitted during normal operations by the following types of sources: treatment systems, diesel-powered generators, fugitive dust-generating activities, mobile sources such as cars and trucks, and miscellaneous activities.

Transportable Treatment Systems. The RRS, MMD-1, and MMD-2 have been designed with redundant controls to prevent the release of chemical agents, treatment reagents, neutralent waste components, or other industrial chemicals into the environment. Treatment and unpack systems would be placed in trailers or other environmental enclosures under negative air pressure to ensure that any gases that would be released would only be released from an exhaust stack after passing through redundant carbon filter elements. These filters would be selected to capture specific chemicals that would be treated. Near real-time monitors would be strategically located to ensure that no agent or other chemicals used in the systems would be emitted.

Tables 5-1 and Table 5-2 show those components of treatment reagents, neutralent wastes, and industrial chemicals that are substances included on the Clean Air Act list of HAPs. The presence of any such substance at a site would not, however, mean that the substance would be emitted to the atmosphere. Because of the design of the CWM treatment systems (see Section 2

and Appendix C) and the fact that most of the substances would be present in liquid form, it would be unlikely for any HAP to be released during normal treatment system operation.

Certain substances subject to the Chemical Accident Prevention Provisions (40 CFR 68) of the Clean Air Act would also be present at treatment sites as components of treatment reagents, neutralent wastes, and industrial chemicals. Such substances could include allyl alcohol, arsine, butane, 1-butene, 2-butene, 2-butene-cis, 2-butene-trans, chlorine, chloroform, cyanogen chloride, hydrocyanic acid, hydrogen, isobutane, isopentane, and vinyl chloride. Regulatory threshold limits for these substances are 10,000 pounds or more for all substances except arsine (1,000 pounds), chlorine (2,500 pounds), and hydrocyanic acid (2,500 pounds). Most of these substances would be present only in very low concentrations and would not be expected to exceed their thresholds. Chloroform, a component of RRS reagents, could be the substance present in the largest quantity, but would not be expected to be present above its threshold of 20,000 pounds (approximately 1,600 gallons). If any substance were to be present above its threshold at a specific site, the Army would prepare a Risk Management Plan and comply with the other applicable requirements of the Chemical Accident Prevention Provisions. This determination would be made on a site-specific basis. If the treatment system were to be deployed to an existing stationary source, such as a military installation, the determination would also need to consider any amounts of these substances already present at that source, as discussed below.

Diesel-Powered Generators. Diesel-powered generators could be used to generate electrical power during treatment system operation at various sites, either as the primary source of power or as an emergency backup (see Section 5.3.7.3). When used, diesel-powered generators would emit such criteria pollutants as nitrogen oxides, sulfur oxides, carbon monoxide, hydrocarbons, and particulate matter. Diesel-powered generators would also emit small quantities of some HAPs, such as acetaldehyde, acrolein, benzene, 1,3 -butadiene, formaldehyde, naphthalene, propylene, toluene, and xylenes (U.S. Environmental Protection Agency, 1996a). Emission quantities would be site-specific and would depend upon such factors as the number of generators used, the number of hours of operation, and the amount of power generated. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

The RRS would have a 65-kilowatt generator to be used should local electrical power be unavailable and a 15-kilowatt backup generator should a power failure occur. As currently designed, the MMD-1 would have a generator capable of producing the 480 kilowatts of electricity needed to fully run the system if local power were not available and a 125-kilowatt emergency generator. The MMD-2 would require about 1,335-kilowatts of electrical power for normal operations and a 500-kilowatt diesel generator for emergencies (See Section 2 and Appendix C).

Table 5-1. Substances Listed as Hazardous Air Pollutants that Could be Present in Rapid Response System Reagents and Neutralent Wastes[a]

Treatment Process		
Blue	**Red**	**Charcoal or Charcoal-L**
1,1,2-trichloroethane	1,1,2-trichloroethane	1,1,2-trichloroethane
1,1-dichloroethylene	1,1-dichloroethylene	1,1-dichloroethylene
Chloroform	Acetaldehyde	Carbon tetrachloride
Tetrachloroethane	Chloroform	Chloroform
Tetrachloroethylene	Chlorovinylarsonic acid	Chlorovinylarsonic acid
Trichloroethylene	Tetrachloroethane	Dichloroethane
Vinyl chloride	Tetrachloroethylene	Hexachloroethane
Arsenic	Trichloroethylene	Tetrachloroethylene
Cadmium	Vinyl chloride	Trichloroethylene
Chromium	Arsenic	Vinyl chloride
Lead	Cadmium	Arsenic
Mercury	Chromium	Cadmium
Nickel	Lead	Chromium
Selenium	Mercury	Lead
	Nickel	Mercury
	Selenium	Nickel
		Selenium

[a] Hazardous air pollutants are identified pursuant to Section 112(b) of the Clean Air Act.

Table 5-2. Substances Listed as Hazardous Air Pollutants that Could be Present in Munitions Management Device and Explosive Destruction System Reagents and Neutralent Wastes and in Industrial Chemicals[a]

Treatment Process			Industrial Chemicals
Sarin (GB)	**Mustard (HD)**	**VX**	
2,4-dinitrotoluene	1,1-dichloroethylene	1,1-dichloroethylene	Benzene
Benzene	2,4-dinitrotoluene	1,2-dichloroethane	Bromobenzyl cyanide (CA)
Hexachlorobenzene	Chloroform	Benzene	Carbon tetrachloride
Hexachlorobutadiene	Hexachlorobenzene	Carbon tetrachloride	Chloroacetaphenone (CN)
Methyl ethyl ketone	Hexachlorobutadiene	Ethylene glycol	Chlorobenzene
Arsenic	Methyl ethyl ketone	Terachloroethylene	Chloroform
Chromium	Tetrachloroethylene	Trichloroethylene	Cyanogen chloride
Lead	Trace metals	Vinyl chloride	Hydrogen Cyanide (AC)
Nickel	Trichloroethylene	Chromium	Nitrobenzene
	Vinyl chloride	Lead	Phosgene (CG)
	Arsenic	Selenium	White Phosphorous
	Chromium		
	Nickel		
	Selenium		

[a] Hazardous air pollutants are identified pursuant to Section 112(b) of the Clean Air Act.

Table 5-3 presents the estimated annual emissions of criteria pollutants and HAPs that could be released at a site under the three deployment scenarios discussed in Section 5.1 if the primary generators for each treatment system present were to be used for a full year at the site. The use of generators for this period could encompass both the operational phase and other life-cycle phases at a site. It should be noted that life-cycle activities would likely require less than a full year at most sites. Table 5-3 also shows the estimated annual emissions that could be released if the emergency backup generators were to be used at the site for 500 hours during the course of the year. At sites where generators were used, primary and backup generators would rarely, if ever, be used at the same time.

Table 5-3 also identifies selected preconstruction regulatory thresholds at which certain air quality reviews, permits, and/or approvals could be necessary if annual estimated emissions from generators (alone or in combination with other sources) potentially equaled or exceeded the threshold. (If the treatment system were to be deployed to an existing stationary source, such as a military installation, emissions from that existing stationary source would also need to be considered in determining whether regulatory thresholds could potentially be exceeded, as discussed below.) Based on the assumptions and estimated emissions from Table 5-3, certain of these preconstruction regulatory thresholds could potentially be exceeded for criteria pollutants at some sites under two of the deployment scenarios if primary generators were used full time for a year at the site. These regulatory thresholds would not be exceeded by the use of emergency generators alone under any of the deployment scenarios. Emissions of hazardous air pollutants would be expected to be well below regulatory thresholds for all deployment scenarios for both types of generators.

If primary generators were used full time for a year under the assumptions in Table 5-3, conformity determinations (see Section 4.1.2.2) could be required for sites in ozone nonattainment and maintenance areas under both the RRS and MMD-2 and the RRS, MMD -1, and MMD-2 deployment scenarios. Conformity determinations could also be required for sites in nitrogen dioxide nonattainment and maintenance areas under the RRS, MMD-1, and MMD-2 deployment scenario. The need for any specific controls and other mitigation measures would be determined as part of the site-specific conformity determination.

If primary generators were used full time for a year, a Nonattainment New Source Review permit or approval (see Section 4.1.2.2) could be required for sites in nitrogen dioxide nonattainment and unclassifiable areas under the RRS, MMD-1, and MMD-2 deployment scenario, and possibly under the RRS and MMD-2 deployment scenario, providing the site where they were located was an existing major source. A PSD permit or approval (see Section 4.1.2.1) could be required for sites in nitrogen dioxide nonattainment and unclassifiable under both the RRS and MMD-2 and the RRS, MMD-1, and MMD-2 deployment scenarios, providing the site where they were located was an existing major source. A Title V operating permit (see Section 4.1.3) could also be required, based on the estimated nitrogen oxide emissions, at some sites in both attainment and nonattainment areas

Table 5-3. Estimated Annual Air Emissions from Diesel-Powered Generators Under Normal Operations and Comparison to Selected Preconstruction Regulatory Review Thresholds

Generator Use/Air Pollutant	Emissions[a] (tons/year) Deployment Scenario[c]			Emission Threshold for Preconstruction Review[b] (tons/year)			
				New Source Review (NSR)		Comformity Determination[d]	
	RRS	RRS and MMD-2	RRS, MMD-1, and MMD-2	PSD[e]	Nonattainment NSR[f]	Nonattainment Area	Maintenance Area
Primary Power Supply[g]							
Criteria Pollutant							
Carbon monoxide	1.3	23.3	32.9	100	100	100	100
Hydrocarbons[h]	0.5	3.3	6.9	n	n	i	i
Nitrogen oxides	6.0	58.0	102.6	40	40	100	100
Ozone	j	j	j	40[l]	40[l]	10-100[k]	50[l]; 100[m]
$PM_{10}/PM_{2.5}$	0.4/0.4	1.8/1.8	5.0/4.9	15	NA	70-100[k]	100
Sulfur oxides	0.4	13.3	16.3	40	40	100	100
Hazardous Air Pollutants (HAPs)							
1,3-Butadiene	0.00005	0.00005	0.0005	10	10	10	10
Acetaldehyde	0.001	0.002	0.01	10	10	10	10
Acrolein	0.0001	0.0005	0.001	10	10	10	10
Benzene	0.001	0.04	0.05	10	10	10	10
Formaldehyde	0.002	0.005	0.02	10	10	10	10
Naphthalene	0.0001	0.006	0.007	10	10	10	10
Propylene	0.004	0.1	0.2	10	10	10	10
Toluene	0.0006	0.01	0.02	10	10	10	10
Xylenes	0.0004	0.01	0.01	10	10	10	10
Total HAPs	0.009	0.2	0.3	25	25	25	25

Table 5-3. (Continued)

Generator Use/Air Pollutant	Emissions[a] (tons/year) Deployment Scenario[c]			Emission Threshold for Preconstruction Review[b] (tons/year)			
				New Source Review (NSR)		Comformity Determination[d]	
	RRS	RRS and MMD-2	RRS, MMD-1, and MMD-2	PSD[e]	Nonattainment NSR[f]	Nonattainment Area	Maintenance Area
Emergency Power Supply[o]							
Criteria Pollutant							
Carbon monoxide	0.03	1.1	1.4	100	100	100	100
Hydrocarbons[h]	0.01	0.44	0.5	[n]	[n]	[i]	[i]
Nitrogen oxides	0.2	5.3	6.6	40	40	100	100
Ozone	[j]	[j]	[j]	40[l]	40[l]	10-100[k]	50[l]; 100[m]
$PM_{10}/PM_{2.5}$	0.01/0.1	0.4/0.4	0.5/0.5	15	NA	70-100[k]	100
Sulfur oxides	0.01	0.4	0.4	40	40	100	100
Hazardous Air Pollutants (HAPs)							
1,3-Butadiene	0.000001	0.00005	0.00006	10	10	10	10
Acetaldehyde	0.00003	0.0009	0.001	10	10	10	10
Acrolein	0.000003	0.0001	0.0001	10	10	10	10
Benzene	0.00003	0.001	0.001	10	10	10	10
Formaldehyde	0.00004	0.001	0.002	10	10	10	10
Naphthalene	0.000003	0.0001	0.0001	10	10	10	10
Propylene	0.00009	0.003	0.004	10	10	10	10
Toluene	0.00001	0.0005	0.0006	10	10	10	10
Xylenes	0.00001	0.0003	0.0004	10	10	10	10
Total HAPs	0.0002	0.008	0.01	25	25	25	25

Table 5-3. (Concluded)

[a] Emissions are calculated using USEPA (U.S. Environmental Protection Agency, 1996a) factors for industrial diesel generators (for the RRS and the MMD-1) and for a large stationary diesel engine burning 0.4 percent sulfur content diesel fuel (for the MMD-2).

[b] This identifies selected regulatory thresholds at which certain preconstruction reviews, permits, or approvals might be necessary if estimated emission rates equaled or exceeded the threshold. See Sections 4.1.2.

[c] The deployment scenarios are described in Section 5.1. All scenarios assume that each treatment system would operate 260 days per year.

[d] Applies for conformity determinations in nonattainment and maintenance areas. If direct plus indirect emissions from a federal action equal or exceed the specified threshold for any criteria pollutant for which the area is in nonattainment or maintenance status, a conformity determination would be required as discussed in Section 4.1.2.2 before construction could commence. Any source with hazardous air pollutant emissions equaling or exceeding the specified thresholds would also require reviews, permits, or approvals.

[e] Applies for New Source Reviews in attainment and unclassifiable areas. A major source or modification to a major source with criteria pollutant emissions equaling or exceeding a specified threshold would need a permit or approval that meets requirements discussed in Section 4.1.2.1 before construction could commence. Any source with hazardous air pollutant emissions equaling or exceeding the specified thresholds would also require reviews, permits, or approvals.

[f] Applies for New Source Reviews in nonattainment and unclassifiable areas. A major source or modification to a major source with criteria pollutant emissions equaling or exceeding a specified threshold would need a permit or approval that meets requirements discussed in Section 4.1.2.2 before construction could commence. Any source with hazardous air pollutant emissions equaling or exceeding the specified thresholds would also require reviews, permits, or approvals.

[g] Annual emissions for the primary power supply are calculated based on 2,080 hours at full power and 6,680 hours at half power.

[h] Emissions listed are for total organic compounds; volatile organic compounds are one component of total organic compounds; volatile organic compounds (along with nitrogen oxides) can lead to the formation of ozone; the ozone thresholds in this table are based on emissions of volatile organic compounds and/or nitrogen oxides.

[i] There are no specified thresholds for hydrocarbons; the volatile organic compound component of hydrocarbon emissions (along with nitrogen oxides emissions) are used to determine if ozone thresholds are reached or exceeded.

[j] The ozone thresholds are based on hydrocarbon (volatile organic compound) emissions and nitrogen oxides emissions (40 CFR 51.853[b]).

[k] The applicable emission threshold falls within the specified range and depends on the degree of nonattainment (40 CFR 51.853[b]).

[l] This threshold is based on volatile organic compound emissions.

[m] This threshold is based on nitrogen oxides emissions.

[n] There are no specified thresholds for hydrocarbons; the volatile organic compound component of hydrocarbon emissions are used to determine if ozone thresholds are reached or exceeded.

[o] Annual emissions from the emergency power supply are calculated based on an assumed 500 hours of operation per year.

CFR – Code of Federal Regulations

MMD-1– Munitions Management Device-Version One

MMD-2– Munitions Management Device-Version Two

$PM_{2.5}$ – Particulate matter with a diameter $\leq$2.5 microns

PM_{10}– Particulate matter with a diameter of $\leq$10 microns

PSD– Prevention of Significant Deterioration

RRS– Rapid Response System

under both the RRS and MMD-2 and the RRS, MMD-1, and MMD-2 deployment scenarios. The need for any specific controls and other mitigation measures would be determined as part of the site-specific New Source Review and Title V review processes.

Fugitive Dust-Generating Activities. Various operational activities would generate particulates in the form of fugitive dust. Sources of fugitive dust would include any activities that physically disturb the ground surface at the site. Cleared areas could also be a source of wind-blown dust. Personal vehicles and trucks would also generate fugitive dust when traveling over paved and unpaved roads.

The amount of fugitive dust emissions generated would be very site-specific and would depend upon such factors as the amount of land disturbed, the specific activities conducted at the site and the timeframe over which they are conducted, the number and types of vehicles used at the site, the vehicle-miles traveled on paved and unpaved roads, the dust suppression and other mitigating measures used at the site, and such local factors as wind speed and the silt and moisture content of site soils.

State and local regulations and military installation requirements could dictate controls, such as covering trucks hauling dirt, sand, soil, or other loose material; applying water or other dust suppressants; or restricting activities on days with unfavorable meteorological conditions. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

Mobile Sources. Mobile sources of emissions would consist primarily of trucks and personal vehicles. Trucks would be used to transport treatment reagents and other supplies, and possibly CWM items, to the site and to transport neutralents and other wastes from the site. Personal vehicles would be used to transport workers to and from the site.

The mobile sources would release criteria pollutants. Emission quantities would be site-specific and would depend upon such factors as the vehicle-miles traveled by the cars and trucks.

Miscellaneous Sources. Various other activities, such as painting, solvent cleaning, and equipment maintenance, would produce small amounts of solvent-based emissions that could include both HAPs and other volatile organic compounds. These emissions would be extremely site-specific and would depend on the activities conducted, the materials used, and the timeframe over which they are used. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

5.3.1.2 Air Quality Impacts

Air quality impacts from normal operations would be extremely site specific and would depend upon such factors as the specific types and quantities of air pollutants emitted by the various operational activities, existing air quality in the area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts

would have to be in compliance with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented, as necessary, prior to the start of operations.

All necessary air quality reviews, permits, and approvals would be obtained both before the transportable treatment system was set up at a specific site and before any operations commenced. As noted above, Title V operating permits could be required at some sites. The need for additional controls and mitigating measures would be identified and implemented based on the reviews, permits, and approvals. The necessary reviews, permits, and approvals would be site specific and, as discussed above and in Section 4.1, would depend upon such factors as the types and quantities of emissions released, existing air quality in the area, and state and local regulations that are in addition to, or more stringent than, federal requirements.

As discussed in Section 5.2.1, the need for certain reviews, permits, and approvals depends upon the total annual quantity of regulated pollutants emitted, or potentially emitted, by the source, which in this case is the transportable treatment system. Emissions from site operations would be just one component of the total emissions that need to be considered. Emissions from other relevant life-cycle activities, such as treatment system setup, closure, and demobilization, would also need to be considered in determining total emission quantities and the specific reviews, permits, and approvals necessary before both construction and operation could commence.

Furthermore, the need for certain reviews, permits, and approvals would also depend upon whether the transportable treatment system constituted a new source or whether it was being setup at an existing stationary source, such as a military installation, where it would be considered a modification to the source. In the former case (when the transportable treatment system would be a new source), the need for these reviews, permits, and approvals would be determined based solely on the emissions from the transportable treatment system life-cycle activities. In the latter case, the need for reviews, permits, and approvals would be determined considering the emissions from the transportable treatment system life-cycle activities in conjunction with the emissions from the existing stationary source. For example, even if the existing source did not itself constitute a major source subject to certain regulations, the incremental emissions from the transportable treatment system could be sufficient for the modified existing source to become a major source now subject to the applicable review, permit, or approval.

5.3.2 Noise

During normal treatment operations, noise generated by a variety of on-site and off-site activities could potentially cause impacts to nearby residents, businesses, and other noise-sensitive receptors. Noise-generating activities during normal treatment operations could include the following:

- Operation of diesel-powered generators during a loss of local power or for normal operation (when no locally available power is available for use)
- Operation of air-handling equipment for heating, ventilating, and air conditioning (HVAC) and air-filtration
- Intentional and controlled detonation of decontaminated munitions bodies with explosive components in explosive containment chambers
- Transport of CMW, supplies, material, and waste during normal operations by truck or helicopter
- Workers commuting to and from the treatment site

Noise would primarily come from equipment at the non-stockpile CWM processing and treatment site. However, some noise would be generated off-site by trucks delivering supplies or transporting wastes to disposal or treatment facilities.

The level of noise would be dependent on site-specific factors including the number and type of transportable chemical treatment and support systems present, the amount of truck and automobile traffic to and from the site, and the proximity of noise-sensitive receptors.

The largest source of noise would likely be one or more diesel-powered generators to be used as either standby or full-time power sources. Standby or emergency generators would be used to temporarily provide electric power during a loss of local power until either local power could be restored or processing and treatment operations are placed in a safe standby status. Standby generators would only be operated periodically to test the generators. Full-time generators could be needed at rural sites where no local power was available. Such full-time power generators would be operated continuously.

Another potential source of noise during normal operations would be the explosive detonation of munitions with explosive components in the EDS and MMD-2. In the explosive containment chamber of the EDS, controlled detonation of shaped charges would be used to access the CWM within the munitions. In the MMD-2 explosive containment chamber, a munition with explosive components would be cut and drained of CWM. Detonation of explosive components would occur only by accident, but would be contained in the chamber. Most of the noise in either system would be contained within the explosive containment chambers.

Increased noise levels from transport of equipment and material would depend upon several factors that include the number and types of transportable chemical treatment systems at a site, and the amount of non-stockpile CWM to be processed and treated. As discussed in Section 5.3.8, the frequency of truck trips to and from the site would likely amount to only a few per week once operations were under way. Truck traffic onsite could add additional noise if access roads from the recovery site passed near noise-sensitive receptors. Transport

by road would not be expected to significantly increase local noise levels, except when a large and continuous number of truck shipments would occur in rural areas.

Prior to deployment of the transportable chemical treatment and support systems, analyses would be conducted to determine if noise generated by site equipment and operations would adversely affect surrounding areas. Where noise generation would be a problem, noise mitigation measures would be employed. Mitigation measures could include siting noisy equipment away from sensitive areas, shielding noise sources, and scheduling noisy operations to minimize adverse impacts on nearby sensitive activities. Electric generators would be equipped with appropriate noise abatement equipment (for example, mufflers, sound insulation, containment housings) to limit radiated noise. Outdoor noise levels at sensitive receptor locations would be keep to a maximum DNL of 65 dBA, in accordance with AR 200-1. Additional noise abatement measures might be required in areas where the 65 dBA would be inappropriate.

5.3.3 Geology, Minerals, and Soils

Soils would be affected at the treatment site for the duration of the treatment operation, which could last for several months to several years. The effects would be site-specific and depend on the previous history of site use, mitigating measures implemented during the site preparation phase, and characteristics of the specific site. Additional compaction could occur from operation of equipment and other activities at the site and from the structures placed on the site. Erosion of soils would be controlled by seeding grasses on graded areas and by erosion control measures required as part of the sediment control plan implemented during site preparation.

Access to economically important subsurface minerals underlying or near the site would be restricted or eliminated during site operation. These restrictions would only be temporary for the duration of the period while site activities were ongoing. It is not likely that site operation activities would permanently foreclose access to subsurface minerals.

5.3.4 Groundwater

Groundwater resources should not be significantly affected by normal site operations. No additional subsurface activities that could affect groundwater are likely to occur. No groundwater wells would be operated at the site. Potable water would be supplied by local utilities or provided in tanks filled from a water supply system elsewhere and transported to the site as needed. Domestic and uncontaminated wastewater would be discharged to a local sanitary sewer system and treated at a wastewater treatment facility or collected in holding tanks and transported to a wastewater treatment facility off the site. Normal leaks of petroleum products from equipment operating on the site should not be enough to pose a significant risk of groundwater contamination. Hazardous chemicals and wastes would be

handled in containers according to the requirements of RCRA or CERCLA and would be removed from the site periodically.

5.3.5 Ecological Environment

Effects on the ecological environment that began during site preparation could continue during site operation. The amount of land that could continue to be affected could range from about 1 acre for an RRS alone (scenario 1) to about 6 acres for scenario 2 (RRS, MMD-1, and MMD-2). These effects would depend on the circumstances of each specific site. Potential ecological impacts during operation would be considered as part of the site-selection process. Impacts identified would be a factor in selecting the site location and in determining mitigating measures required.

5.3.5.1 Upland Environment

Habitat on the site would be lost or reduced in ecological value while site operations take place for several months to one or two years. The extent of these impacts would depend on the prior habitat value of the site and any mitigating measures that would have been identified during site planning as needed during site operation.

5.3.5.2 Wetland and Floodplain Environments

Any wetlands lost during site preparation would continue to be affected during site operation. This impact would be in accordance with the conditions of the permit issued for activities in wetlands issued by the U.S. Army Corps of Engineers with the concurrence of the USEPA under Section 404 of the Clean Water Act before any activities began at the site.

Sediment in storm water runoff from the site could also affect adjacent wetlands. Adverse effects are likely to be controlled to an acceptable level or eliminated by sediment control management measures that would be required by many states and by all military installations. State and/or installation authorities must approve a site sediment control plan before any activities begin at a site. Sediment control management measures would have been installed before site preparation activities commenced. Sediment control management measures must be continued during site operation. Any sediment control measures in place must be inspected and kept in proper operating condition during the site operation period. The amount of sediment in storm water runoff during site operation is likely to be small because bare areas would be revegetated, gravel would likely be spread on ground areas used by equipment to reduce erosion, and other operating areas could be paved surfaces.

If the operating site is in a floodplain, the Army would comply with Executive Order 11988, Floodplain Management. Under this Order, the Army must consider the impacts of its activities in a floodplain and implement measures to minimize these impacts. These considerations would be carried out as part of the site selection phase and would be in place during site operations.

5.3.5.3 Aquatic Environment

Storm water runoff from the site into adjacent aquatic environments could contain some sediment and contaminants because of soil disturbances during site operation and from leaks of fuel, oil, and lubricants. Domestic wastewater would also be generated on site.

Sediment and Contaminants in Runoff. Sediment and contaminants in storm water runoff from the site could affect aquatic environments adjacent to the site during site-operation. The amount of sediment in runoff would be site-specific but is likely to be small at any site. Adverse effects are likely to be controlled to an acceptable level or eliminated by site sediment control management measures that would be required by many states and by all military installations. State and/or installation authorities must approve a site sediment control plan before site preparation activities begin. Any sediment control measures in place must be inspected and kept in proper operating condition during the site operation period. The amount of sediment in storm water runoff during site operation is likely to be small because bare areas would be revegetated, gravel would likely be spread on ground areas used by equipment to reduce erosion, and other operating areas could be paved surfaces.

Storm water runoff could contain small quantities of hydrocarbon contaminants from normal leaks of fuel, oil, or lubricants from vehicles and equipment during site operation. The amount is likely to be small, and the amount in runoff would likely be typical of that from any other light industrial site of this size.

It is possible that a National Pollutant Discharge Elimination System permit issued under the provisions of the Clean Water Act also may be required if storm water runoff drains into a collecting system that discharges to surface waters. This permit would set limits on sediment and contaminants in the discharge. If a permit already exists for discharges from the area chosen for treatment system operation, the permit conditions would have been reviewed to determine if the permit must be modified. This review would take place before site preparation activities would begin. Site activities could not take place until the permit was issued or modified.

Domestic Wastewater. Domestic and other uncontaminated wastewater generated during site operation would be discharged to a wastewater treatment system, which would usually discharge its effluent to surface waters. Site wastewater could be discharged directly to a wastewater system at the site or to portable domestic waste-collection systems brought to the site. Portable systems would be discharged to an off-site wastewater treatment system. These discharges would be regulated under the National Pollutant Discharge Elimination System permit issued to the wastewater treatment facility.

5.3.5.4 Threatened and Endangered Species

Any impacts on threatened and endangered species that occurred during site preparation would likely continue during site operation. These impacts would have been determined during site planning, and coordination with the U.S. Fish and Wildlife Service or the

National Marine Fisheries Service and with state agencies would have been completed during that phase. Impacts during site operation would be site specific and could include loss of habitat, reduced habitat quality, and effects on habitat use or reproductive success in adjacent areas. These impacts would continue for the period of site operation of several months to one to two years. Site operation would be carried out in accordance with any mitigating measures determined to be required in consultation with the responsible federal, tribal, and state agencies.

5.3.6 Waste Management

The operation and pre-operational survey of each of the four types of treatment systems would generate a variety of waste streams at each site. Tables 3-4 through 3-7 of Section 3 list the waste streams that could be generated by each transportable treatment system. These waste streams include: neutralents; repackaged industrial chemicals; decontaminated metal containers, munition casings, and metal fragments; bead blast residue; spent carbon and spent filter elements; spent decontamination solutions and rinse waters; decontaminated and uncontaminated overpacks and packing materials; used personal protective equipment; laboratory wastes; spent cleanup materials; trash and similar wastes; HVAC condensate; sanitary waste; and spent oil and lubricants.

While most of these waste streams would be generated by each of the four systems, the specific composition of many of the waste streams (e.g., neutralents, repackaged industrial chemicals, spent decontamination solutions) would be dependant upon the specific CWM being treated at the site as well as the site-specific composition of that CWM. Tables 3-8 through 3-12 present information on the composition of the neutralents generated from processing various chemical agents and the industrial chemical phosgene in the different treatment systems. Table 1-2 identifies industrial chemicals that could be encountered and repackaged.

As discussed in Section 3.1.10, all waste streams directly associated with chemical agent would be sent to a permitted, commercial, RCRA hazardous waste TSDF for management, except for certain metallic wastes that would be sent to a DoD smelter. The wastes associated with agent would include neutralents and some of the spent filter elements, used personal protective equipment, laboratory wastes, spill cleanup materials, and spent decontamination solutions and rinse waters (see Tables 3-4 through 3-7). Decontaminated overpacks, metal containers, munition casings, metal fragments, and metallic packing materials from the MMD-1 and MMD-2 would generally be sent to a DoD smelter (such as Rock Island Arsenal, Illinois) for smelting and eventual recycling. In addition, all repackaged industrial chemicals would also be sent to a permitted, commercial hazardous waste TSDF for management. The wastes would all be sampled and analyzed in accordance with RCRA requirements.

The remaining waste streams generated during site operations would also be tested for the presence of chemical agent. Any waste stream identified as having agent present would be decontaminated, analyzed in accordance with RCRA requirements, and then sent to a

permitted, commercial hazardous waste TSDF for management. The rest of the waste streams would each be sampled and analyzed in accordance with RCRA requirements to determine if it is a RCRA hazardous waste or a solid (nonhazardous) waste. If it were a hazardous waste, it would be sent to a permitted, commercial hazardous waste TSDF. If not, it would be sent to a permitted solid waste management facility or a wastewater treatment facility, as appropriate to the waste stream. However, spent oils and lubricants would be sent to appropriate recycling facilities. Metal containers, munition casings, metal fragments, and metallic packing materials from the MMD-1 and MMD-2 would generally be sent to a DoD smelting facility for smelting and eventual recycling. Uncontaminated overpacks would generally be reused, rather than smelted or disposed. Non-agent contaminated overpacks would also generally be cleaned and reused, rather than smelted or disposed. Some sanitary waste and some liquid waste could be discharged directly to a sanitary sewer system rather than being containerized and transported to a wastewater treatment facility.

The environmental consequences of managing those wastes that could be discharged to a sanitary sewer system or transported to a wastewater treatment facility are discussed in Section 5.3.7.2. Such wastes include sanitary wastes, as well as those rinse waters, spent decontamination solutions, liquid laboratory wastes, and HVAC condensates that are not RCRA hazardous wastes and/or associated with chemical agent. The management of all the other wastes is discussed below.

The specific facilities used to manage each waste stream would be determined on a site-specific basis and would depend upon the site-specific nature and composition of the waste stream. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process. The wastes would be managed in accordance with all federal, tribal, state, and local laws and regulations applicable at the treatment site and at the waste management facility. Compliance with these laws and regulations would be addressed in the site-specific analyses and documentation prepared for each site. Section 4.6 discusses the federal waste management regulations that would apply in managing the wastes at each type of facility.

The NSCMP has in place a program of auditing and review of TSDFs that treat NSCMP wastes. This program would apply to TSDFs that accept and treat wastes from the transportable treatment systems. In selecting a specific, permitted, commercial TSDF to receive Army wastes, the Army would consider the past compliance history of the facility and the type of monitoring and pollution control equipment in use at the facility. The Army would also perform continuing assessments and audits of the performance of all hazardous waste TSDFs selected to ensure that these facilities remain in compliance with all applicable environmental regulations and safety requirements.

5.3.6.1 Waste Quantities

Table 5-4 shows the quantity of waste estimated to be generated annually by transportable treatment systems operating under each of the deployment scenarios described in Section 5.1. Estimated quantities are presented for neutralents, metals sent to smelting and recycling, and "other wastes." "Other wastes" include those wastes other than neutralents, metals sent to recycling, and wastes sent to wastewater treatment, that would routinely be generated on a daily basis from each treatment system. While data are not presently available to estimate the quantity of all of the "other wastes" that could be generated (see Section 3.1.10), the quantity in the table includes the most significant components. Some additional wastes, such as spent filter elements, spent oils and lubricants, and spill cleanup materials, would be generated only occasionally; data are not available to estimate the quantity of such occasional wastes that would be generated annually.

As discussed above, the neutralents would be sent to permitted, commercial hazardous waste management TSDFs. Some of the wastes included in the "other wastes" category would also be sent to these hazardous waste TSDFs, while some could be sent to permitted solid waste management facilities.

The following sections discuss how managing the wastes generated under the four deployment scenarios could impact waste management capacities on a national scale. Site-specific impacts to waste management facility capacities would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

Hazardous Waste. Table 5-5 shows the total annual quantity of RCRA hazardous waste managed at off-site hazardous waste TSDFs in the United States. Off-site TSDFs are generally the commercial TSDFs. (On-site TSDFs tend to be dedicated to managing only those wastes generated by an associated facility, such as a manufacturing plant. Wastes from the transportable treatment systems would not be sent to such TSDFs, but rather to the commercial TSDFs.)

Table 5-5 also shows the total annual quantity of RCRA hazardous waste managed by specific management methods at these off-site TSDFs, as well as the number of offsite TSDFs at which each management method was used. The management methods listed in the table are those that have been specifically identified in the referenced report (U.S. Environmental Protection Agency, 1997) and that might typically be used in managing wastes from the transportable treatment systems. All other management methods specifically identified in the report that are not likely to be used in managing wastes from the transportable treatment systems are aggregated in Table 5-5 under the listing of "other." While the listed management methods encompass most of the RCRA land disposal restriction technology-based standards that could apply to the transportable treatment system wastes (see Section 4.6.1.3), the USEPA report does not categorize the management methods according to those technology-based standards.

Table 5-4. Estimated Quantity of Waste Generated Annually under Transportable Treatment System Deployment Scenarios

Waste Type	Deployment Scenario[a]			
	RRS	RRS and MMD-2	RRS, MMD-1, and MMD-2	All Systems Deployed[b]
Neutralents[c]				
Gallons per year	3,900	160,000	316,000	960,000
Tons per year[d]	25	670	1,320	4,000
Other Wastes[e]				
Tons per year	20	200	330	1,200
Metals to Recycling				
Tons per year	–	50[f,g]	100[g,h]	240[g,i]

[a] The deployment scenarios are described in Section 5.1. All scenarios assume that each treatment system would operate 260 days per year.

[b] Under this scenario, two RRSs, two MMD-1s, three MMD-2s, and two EDSs would be deployed.

[c] The quantity of neutralent generated per day by each individual treatment system is given in Table 3-13.

[d] For the MMD-1, MMD-2, and EDS, the neutralent is assumed to have approximately the same weight as water (about 8.3 pounds per gallon). For the RRS, the neutralent is assumed to be approximately 1.5 times the weight of water. (See Tables 3-8 through 3-12 for the neutralent composition.)

[e] The specific wastes included under "other wastes" and the quantity generated per day by each type of treatment system are presented in Table 3-13. The EDS is assumed to generate approximately the same quantity of "other wastes" as the MMD-2.

[f] Up to approximately 520 decontaminated munition casings or metal containers could be sent to a DoD smelter for smelting and eventual recycling per year (see Table 3-13).

[g] The weight of the metal being recycled would depend on the site-specific mix of CWM treated at each particular site. To be conservative, the analysis in this environmental impact statement assumes that each item would have the weight of an unfilled 8″ artillery projectile—185 pounds (SciTech Services, 1998).

[h] Up to approximately 1,040 decontaminated munition casings or metal containers could be sent to a DoD smelter for smelting and eventual recycling per year (see Table 3-13).

[i] Up to approximately 2,600 decontaminated munition casings or metal containers could be sent to a DoD smelter for smelting and eventual recycling per year (see Table 3-13).

RRS – Rapid Response System
MMD-1 – Munitions Management Device–Version One
MMD-2 – Munitions Management Device–Version Two
EDS – Explosive Destruction System

Table 5-5. Quantities of RCRA Hazardous Waste Managed Nationally at Offsite Treatment, Storage, and Disposal Facilities[a]

Waste Management Method	Quantity Managed[b] (tons/year)	Number of Offsite Facilities[c,d]
Incineration	646,000	72
Landfill	812,000	36
Aqueous inorganic treatment	588,000	50
Aqueous organic treatment	208,000	28
Aqueous organic and inorganic treatment	107,000	16
Stabilization	804,000	47
Other treatment	798,000	124
Metals recovery (for reuse)	398,000	50
Other recovery	359,000	103
Other[e]	4,002,000	ND
Total	8,722,000	732[d]

[a] The data are for 1995.

[b] Quantity does not include wastes that are managed only in a storage unit.

[c] This is the number of facilities managing hazardous waste received from offsite generators. The numbers do not include facilities that have only storage units.

[d] Some facilities use multiple management methods. Such facilities are counted only once in the total.

[e] This includes land treatment/application/farming, fuel blending, energy recovery (for reuse), sludge treatment, and deepwell/underground injection, as well as other methods not identified. These management methods would not typically be used for the management of wastes generated by transportable treatment systems.

ND – not determinable

Source: U.S. Environmental Protection Agency, 1997.

Table 5-6 indicates the percentage increase that could occur in the waste being managed at the off-site TSDFs if all the wastes generated under each transportable treatment system deployment scenario were to be managed at these off-site TSDFs. The total quantity of waste managed at all these TSDFs would increase by about 0.06 percent under the maximum deployment scenario (all systems deployed) and by smaller percentages under the other three deployment scenarios. The quantity of waste managed by any specific management method would increase by not more than 0.02 percent for the RRS scenario; by not more than 0.6 percent for the RRS and MMD-2 scenario; by not more than 1.2 percent for the RRS, MMD-1, and MMD-2 scenario; and by not more than 4 percent for the maximum deployment scenario.

Nonhazardous Solid Waste. Not all the waste generated by the transportable treatment systems would be hazardous waste. Some portion of the "other wastes" would be a nonhazardous solid waste that could be disposed of at permitted solid waste management facilities.

Table 5-6. Transportable Treatment System Waste Quantity as a Percentage of Waste Quantity Managed Annually at Offsite RCRA Hazardous Waste Management Facilities[a]

RCRA Management Method	Deployment Scenario[b]			
	RRS	RRS and MMD-2	RRS, MMD-1, and MMD-2	All Systems Deployed[c]
Incineration[d]	<0.01	0.1	0.3	0.8
Landfill[e]	<0.01	0.02	0.04	0.1
Aqueous inorganic treatment[f]	<0.01	0.1	0.2	0.7
Aqueous organic treatment[f]	0.01	0.3	0.6	1.9
Aqueous organic and inorganic treatment[f]	0.02	0.6	1.2	3.7
Stabilization[e]	<0.01	0.02	0.04	0.1
Other treatment[d]	<0.01	0.1	0.2	0.7
Metals recovery[e]	<0.01	0.05	0.08	0.3
Other recovery[e]	<0.01	0.06	0.09	0.3
Other[e,g]	<0.01	<0.01	<0.01	0.03
All methods[d]	<0.01	0.01	0.02	0.06

[a] The percentage is calculated by dividing the total quantity (in tons) of waste generated for a deployment scenario by the total quantity of hazardous waste managed nationally under each management method at RCRA offsite hazardous waste management facilities. The quantity of waste generated for a deployment scenario is the sum of the neutralents and "other wastes" quantities in Table 5-4, except as otherwise noted. The total quantity of waste managed nationally under each management method is given in Table 5-5.

[b] The deployment scenarios are described in Section 5.1. All scenarios assume that each treatment system would operate 260 days per year.

[c] Under this scenario, two RRSs, two MMD-1s, three MMD-2s, and two EDSs would be deployed.

[d] For this management method, the quantity of waste generated for a deployment scenario is based on the sum of the neutralents and "other wastes" quantities in Table 5-4.

[e] For this management method, the quantity of waste generated for a deployment scenario is based only on the "other wastes" quantity in Table 5-4.

[f] For this management method, the quantity of waste generated for a deployment scenario is based only on the neutralents waste quantity in Table 5-4.

[g] Table 5-5 identifies the management methods included under the category of other.

About 116 million tons of waste is disposed annually at municipal solid waste landfills, and about 36 million tons are burned annually in municipal solid waste incinerators (see Section 5.2.6). To be conservative, even if all the "other wastes" in Table 5-4 were to be disposed of at permitted solid waste landfills, the annual quantity of waste disposed nationwide at such landfills would increase by much less than 0.01 percent under all the scenarios. Similarly, even if all the "other wastes" were to be burned at municipal solid waste incinerators, the annual quantity of waste burned nationwide at such facilities would increase by less than 0.01 percent under all the scenarios.

Metal Recycling. Up to about 240 tons of steel could be sent annually to DoD smelting facilities, such as Rock Island Arsenal in Illinois, for eventual recycling under the four deployment scenarios (see Table 5-4). Recycling this quantity of steel would represent much less than a 0.01 percent increase in the more than 70 million tons of steel recycled annually in the United States (Steel Recycling Institute, 1999).

With regard to Rock Island Arsenal, the facility currently has a smelting capacity of about 3,600 tons per year (Johnson, 1997). If all the steel were to be smelted there, less than 7 percent of the smelter's annual capacity would be required.

Used Oil. On a national basis, recycling the volume of used oil that would be generated by the operation and pre-operational survey of the treatment systems under the four deployment scenarios would represent an insignificant increase in the more than 380 million gallons of all types of waste oil recycled for reuse or burned for energy recovery annually in the United States (U.S. Environmental Protection Agency, 1999a).

5.3.6.2 Management of Hazardous Waste in Accordance with RCRA Land Disposal Restrictions

Various hazardous wastes from the transportable treatment systems would be sent to permitted, commercial, hazardous waste TSDFs for treatment, storage, and disposal. All such wastes would be managed in accordance with all applicable RCRA hazardous waste management requirements (see Section 4.6.1). This would include compliance with permit requirements, general standards (e.g., siting and emergency preparedness), facility-specific standards applicable to specific types of management units (e.g., landfills and various treatment units), and land disposal restrictions.

RCRA places restrictions on the land disposal (e.g., landfilling) of certain hazardous wastes (see Section 4.6.1.3). Various hazardous wastes from the transportable treatment systems would be subject to these land disposal restrictions. Wastes subject to the land disposal restrictions would include the neutralent wastes, repackaged industrial chemicals, spent filters, and various other wastes. Some wastes, such as some industrial chemicals, would be subject to the land disposal restrictions because they are RCRA-listed wastes. Other wastes, such as neutralents, would be subject to the land disposal restrictions because they contain RCRA hazardous constituents and/or exhibit the RCRA hazardous characteristics of

ignitability, reactivity, or corrosivity. The wastes subject to the land disposal restrictions would require treatment before they could be land-disposed.

Tables 4-3 and 4-4 of Section 4 identify the Land Disposal Restrictions that could apply to various wastes from the transportable treatment systems and, for some of theses wastes, the specific treatment method(s) that must be used to treat the waste before it could be land disposed. The types of treatment methods specified for various wastes include combustion, wet air oxidation, chemical or electrolytic oxidation, carbon adsorption, and deactivation. The specific treatment method(s) used for each particular waste stream at a TSDF would be determined on a site-specific and waste-specific basis and would depend on the specific nature and composition of that particular waste stream. After being treated, wastes or residues from the treatment process (e.g., ash) might need further treatment before they could be land-disposed. For example, some ash might require stabilization (see Table 4-4).

The transportable treatment systems are designed specifically to produce neutralent wastes that would be similar to other industrial wastes that are routinely sent to a permitted, commercial TSDF for further treatment and final disposal as regulated by RCRA and other federal and state laws and regulations (Section 4.6.1). A variety of methods can be used by a TSDF to treat and dispose of hazardous wastes safely and properly under RCRA requirements and Land Disposal Restrictions (see Section 4.6.1). The type of treatment method that would be used at a specific TSDF would depend on the specific composition of the waste received to be managed.

Combustion is one technology allowed by RCRA and often used by a TSDF to treat organic and explosive-contaminated wastes to reduce waste volume and to comply with the RCRA Land Disposal Restrictions for final disposal. For some wastes, combustion, such as incineration, may be the only treatment method available for that waste that can meet the Land Disposal Restrictions. A large volume of hazardous waste is currently incinerated as a method of treatment in the United States. In 1995 (the latest year for which data are available), 646,000 tons of hazardous waste were incinerated at off-site facilities (see Table 5-5). Under current RCRA requirements, it is likely that some wastes from transportable treatment systems would be incinerated at a TSDF as the only method available to meet the Land Disposal Restrictions.

Toxic organic compounds contained in hazardous waste are destroyed during combustion by breaking the hazardous compounds into other substances, reducing or eliminating the toxicity. Waste volume of liquids and many solids is also reduced, leaving an ash as residue. Any such ash, sludge, spill residues, emission control dust, or leachate that is produced may also be a hazardous waste under RCRA based on the "derived-from" rule (40 CFR 261.3[c][2][i]) or if the waste exhibits a characteristic of hazardous waste. Under RCRA, the material must be managed as a hazardous waste unless the waste meets the criteria in 40 CFR 261.3(d). If the ash from combustion contains RCRA toxicity characteristic metals (for example, arsenic) above regulatory limits, then the ash might require stabilization prior to land disposal.

RCRA (40 CFR 264 Subpart O) regulates the design, construction, and operation of a hazardous waste incinerator, including emissions from the incinerator (see Section 4.6.1.2). The unit must (1) be operated in accordance with the operating requirements specified in its RCRA permit and (2) be designed, constructed, and maintained so that, when operated in accordance with these operating requirements, it complies with specified performance standards for destruction and removal of hazardous constituents in the waste feed and for limiting emissions of hydrogen chloride (HCl) and particulate matter in the stack gas (40 CFR 264.343 and 264.345). The operating requirements specify allo wable ranges for and continuous monitoring of certain critical parameters, including maximum allowable CO levels in stack emissions, temperature ranges, maximum feed rates, combustion gas velocity, and limits on system design and operating procedures. Waste cannot be fed into the unit unless it is operating within the permit conditions, and operations must cease if the operating conditions deviate from the limits specified in the permit (40 CFR 264.345). During operation, the facility owner/operator must verify by testing that the waste feed is within the physical and chemical limits specified in the permit. These limits may include the waste's heating value, its viscosity, and the hazardous constituent content (40 CFR 264.341). Continuous monitoring of critical parameters, daily (or more frequent) inspections of equipment, and weekly (or more frequent) testing of energy waste feed cutoffs are also required (40 CFR 264.347). Additional requirements may also apply under the Clean Air Act (see Sections 4.1 and 4.6.1.2).

These permit limitations are designed to ensure that an operating incinerator burning a waste with specified physical and chemical characteristics would meet RCRA performance and emission standards. As stated above, neutralent wastes from the transportable treatment system would be similar to other industrial hazardous wastes. Therefore, if the characteristics of the neutralent wastes are acceptable under the permit of an incinerator and the incinerator operates within its permitted parameters, then the incinerator emissions would be similar to emissions when burning any other industrial hazardous waste and would be compliant with RCRA performance standards.

Any hazardous waste incinerator that receives transportable treatment system wastes would be audited under the NSCMP auditing and review program described at the beginning of Section 5.3.6. This program would ensure that the incinerator would destroy the wastes in compliance with regulatory requirements.

The Army would also continue to review and assess other methods and technologies to treat transportable treatment system wastes as they become available in the future. As methods appear feasible, the Army would determine their suitability for these wastes within adequate health, safety, and environmental protection requirements.

5.3.7 Utilities

Utilities needed for the deployment of the transportable chemical treatment systems include electricity, water supply, and wastewater disposal. At most military installations and other sites, it is likely that some or all of the necessary utilities would be available. Some sites would likely lack all utilities, requiring provision of such utilities by portable systems.

5.3.7.1 Water Supply

During normal operations, the water supply needed for the transportable chemical treatment and support systems would increase to the quantities shown in the table below.

Deployment Scenario	Estimated Total System Water Usage (gal/day)
1	2,000
2	6,000
3	8,000

The additional water would be required for the following processes and activities: (1) treatment reagent preparation, (2) lavatory facilities, (3) emergency pers onnel decontamination, (4) drinking water supply, and (5) cleaning and decontamination operations. About a third of the water usage would be for drinking and sanitary needs of the operations and support personnel.

As discussed in Section 3.2.7.1, the existing water supply system would be utilized when available, and transportable potable water tanks would be used when not available rather than establishing a new water supply system.

The impact of the increased water demand on an installations or local water utility would be site-specific and depend on the number of systems deployed and the capacity of the local system. At large military installations and urban sites served by water utilities with excess capacity, the impact would likely be small. At smaller military installations, sites served by water utilities with little or no excess capacity, and sites in arid regions the increased demand could cause adverse impacts on the utility and other water supply users including loss of line pressure, increased sediment entrainment due to higher flows, and increased depletion of local water sources.

5.3.7.2 Wastewater Disposal

During normal treatment operations, wastewater disposal requirements would be determined by sanitary uses of water by personnel onsite and by cleaning operations not associated with agent or hazardous substances. All wastewaters associated with agent operations or associated with hazardous substances would be sampled and analyzed in accordance with Army and RCRA requirements prior to release from the treatment facility. Agent-associated wastewaters and other wastewaters determined to be RCRA hazardous wastes would be sent to a permitted commercial hazardous waste TSDF for management.

Where available, sanitary wastes and other non-hazardous wastewaters would be discharged through existing sanitary or industrial sewer lines to the local wastewater treatment plant. If no sewer lines were available, then wastewater would be containerized and transported to a wastewater treatment facility for disposal. Any pretreatment requirements would be met.

It is estimated that the quantity of wastewater generated during normal treatment operations would be equal to or greater than the quantity of potable water used by personnel for drinking and sanitary purposes. Assuming a usage factor of 25 gallons of potable water per worker, the amount of wastewater generated per day is shown below for each of the deployment scenarios discussed in Section 5.1. The number of personnel includes up to 20 people needed for support functions, such as administrative support, security, food service, and maintenance support. The actual number of support personnel needed would vary by site and nature of deployment.

Deployment Scenario	Personnel	Estimated Sanitary Wastewater (gal/day)
1	38	950
2	78	1,950
3	98	2,450

Additional water could be generated by non-hazardous cleaning operations, but the quantity would be highly variable and site-specific. These wastewater quantities are less than the water supply requirements presented in Section 5.3.7.2 because some of the water supply would be used in treatment reagent preparation and cleaning and decontamination operations.

The impact that this level of wastewater flow would have on an installation or local wastewater treatment facility would be site-specific and depend on the number of treatment systems deployed and the capacity of the local system. At large military installations and urban sites served by wastewater treatment facilities with excess capacity, the impact would likely be small. However, local impacts could occur if local sewer lines did not have the capacity to handle the flow. At smaller military installations and sites served by wastewater systems with little or no excess capacity, the increased demand could cause adverse impacts on the utility and other sewer system users.

As discussed in Section 5.2.7.2, prior to deployment of the transportable chemical treatment and support systems, consultations would be made with local wastewater authorities to determine if the local wastewater disposal infrastructure could accommodate the treatment systems without causing significant adverse impacts. At sites where significant adverse impacts would occur or where a wastewater system is lacking, wastewater would be containerized and transported to a wastewater treatment facility for disposal rather than establishing a new wastewater treatment and disposal system.

5.3.7.3 Electric Utilities

Full power requirements for normal operations under the three deployment scenarios selected for this analysis (see Section 5.1) are shown below.

Deployment Scenario	Power Requirements kW (continuous)
1	65
2	1,400
3	1,880

Local power sources would be used, if available. Some sites may require upgrades to local transmission lines or transformer stations or installation of new lines. Where local power was unavailable or insufficient to meet system requirements, an on-site electrical generating system would be required.

Where local power would be used, the impact on the utility and its users would be site-specific and depend on the number of systems deployed and the capacity of the local power system. At large military installations and urban sites served by an electric utility and line infrastructure with sufficient capacity, the impact would likely be small. At sites served by small electric utilities or lower capacity transmission infrastructures, the impacts on the utility and other users could be significant and include line voltage drops, degradation of line power quality, and system failures.

Prior to deployment of the transportable chemical treatment and support systems, consultations would be made with local electrical utility authorities to determine if the local power system infrastructure could accommodate the treatment systems without causing significant adverse impacts. Where necessary and feasible, upgrades would be made to the local power supply infrastructure to accommodate system requirements. At sites where significant adverse impacts would occur or where an adequate power supply system is lacking, transportable on-site diesel power generators would be used.

5.3.8 Traffic and Transportation

The principal transportation infrastructure used during normal treatment site operations would be highways and roads for transporting (1) chemicals and supplies necessary to operate the transportable chemical treatment and support systems, (2) solid and hazardous waste materials to approved disposal, treatment, or recycling facilities, and (3) operations personnel to and from the site. On-site movement of non-stockpile CWM would generally use on-site access roads.

The impacts to local traffic and transportation systems would be site-specific and vary by local conditions and the characteristics of the actual deployment. However, potential impacts are described below in general terms as to types and general consequences.

Potential transportation impacts that could occur due to normal treatment operations, at either an on-site or an off-site treatment location could include increased traffic congestion, noise, increased risk of transportation accidents, and increased wear on lower-grade road surfaces from truck and automobile traffic generated by normal treatment operations. Impacts of off-site transport of non-stockpile CWM are addressed in Section 5.5.8. Accidents involving the transport of non-stockpile CWM, hazardous wastes, and hazardous materials could also occur that could adversely impact human health and safety. Accidents involving the transport of non-stockpile CWM, hazardous waste, and hazardous materials are addressed in Section 6.4.

5.3.8.1 Local CWM Transport

As discussed in Section 3.1.6, once the transportable chemical treatment and support systems have been setup and preoperational checks and monitoring performed, the non-stockpile CWM items in storage or at a recovery site would be transferred to the processing and treatment systems. For on-site operations, as described in Section 3.1.1, non-stockpile CWM would be transported from the recovery site within the installation or property boundaries to the treatment site by open truck. Since these operations would not use public roads or highways, it is likely that there would be no adverse impacts on local traffic and transportation systems.

5.3.8.2 Commuting

Systems operations personnel would be provided by the operations contractor and would likely come from outside the area surrounding a treatment site location. The number of personnel needed to operate the transportable chemical treatment and support systems under the scenarios described in Section 5.1 are presented in the table below. The number of personnel includes up to 20 people needed for support functions, such as administrative support, security, food service, and maintenance support. These support personnel would likely be local residents. The actual number of support personnel needed would vary by site and nature of deployment.

Scenario	Personnel	Commuter Trips Per Day
1	38	76
2	78	156
3	98	196

If the non-resident personnel were not housed within the installation or property boundaries and each person were to commute by private automobile each day, between 38 and 98 addition vehicle trips could be added to local traffic each morning and afternoon for the duration of the treatment deployment. This commuting would result in continuation of the impacts discussed in Section 5.2.8.2. At the low end (Scenario 1), no impacts would be likely. At the upper end (Scenario 3), the additional traffic could have some adverse effects on local traffic especially near entrances to the military installation or other property where the treatment site is located. Whether or not this would have a significant impact on local traffic patterns would depend on the existing traffic conditions near the site and would be require a site-specific analysis.

If the non-resident personnel were housed on site, up to 20 vehicle trips each morning and afternoon would still be added to traffic near the site as local support personnel commuted to the site. This amount of traffic would likely have no significant impact on local traffic.

Mitigation measures could include scheduling work hours to avoid peak local commuting times, routing worker traffic to avoid high traffic roads when possible and providing for road improvements and traffic control equipment or personnel near the entrance to the treatment installation or property.

5.3.8.3 Material Delivery

Operation of the treatment systems would require delivery of various treatment chemicals and supplies to the treatment site. Transport of these materials would be made by truck and would add traffic to local roads and highways.

The types and amounts of reagents and supplies delivered to a site would depend on the type of treatment systems deployed, the type of CWM to be processed, and the amount of CWM to be processed. The treatment chemicals would be used for neutralizing the different types of CWM and would include such chemicals as MEA, DCDMH, sodium hydroxide, and various organic solvents. Supplies needed for normal operations would include carbon absorption filters, protective equipment, and packaging materials for shipping the wastes. The largest volume of material requiring transport to the treatment site would be the treatment chemicals. The quantity of chemicals needed for normal operations would be equal to or less than the amount of neutralent wastes shown in Table 3-13.

It is likely that the frequency of truck deliveries would be greatest just prior to system startup in order to stockpile chemicals and supplies to initiate and sustain treatment operations. Once treatment operations were underway, the frequency of deliveries would likely drop to a maintenance level of a few deliveries each week or two.

The impact of delivery truck traffic (in combination with waste transport truck traffic discussed below) on local traffic and transportation would depend on the site-specific conditions, especially the type and quality of roads serving the installation or other property, the existing level of truck traffic, and the existing level of traffic congestion. At large installations with a moderate to high level of existing truck traffic and served by high-quality roads, the additional traffic generated by normal treatment operations would likely have little impact. At small installations or non-military properties not accustomed to much truck traffic or served by secondary or lower-grade roads, there may be moderate impacts to local traffic and transportation facilities including increased congestion, noise, increased risk of accidents (with and without hazardous material involvement), and increased wear on road surfaces.

5.3.8.4 Waste Transport

As discussed in Section 4.6, wastes generated from non-stockpile CWM processing and treatment operations and industrial chemical repackaging operations would be temporarily stored on-site until they could be transported for further treatment or disposal at approved

facilities. Receiving facilities would include permitted RCRA hazardous waste TSDFs; permitted solid waste landfills, recycling facilities, and wastewater treatment facilities, as appropriate to the waste being managed. Transport activities to move these wastes to approved facilities would generate additional truck traffic on local, regional, and national roads and highways, which could have impacts on existing traffic and transportation systems.

Tables 3-3 through 3-13 list the types and characteristics of various waste streams that would be generated by the operation (and pre-operational survey) of each of the four types of treatment systems. The tables also identify the process by which each waste stream would be generated, its physical state (e.g., solid or liquid), and the type of facility to which each waste stream would be sent for treatment, storage, and/or disposal.

Several of the waste streams generated from non-stockpile CWM processing and treatment operations and industrial chemical repackaging operations would be characterized as hazardous wastes under RCRA and/or hazardous materials under USDOT Hazardous Material Regulations (49 CFR, Subchapter C; promulgated under the Hazardous Materials Transportation Act). Transport of these hazardous wastes and materials on public roads and highways would have to comply with the provisions of the regulations governing the packaging, marking, labeling, placarding, handling, manifesting, providing emergency response information and transporting of hazardous materials.

Liquid wastes would be contained in drums, 350-gallon intermediate bulk container (IBC) totes, or tanker trucks (MMD systems) meeting USDOT specifications. Solid wastes would be contained in drums, cubic yard boxes, or roll-off boxes meeting USDOT specifications for transport to an approved TSDF or other appropriate facility.

The quantities of waste and the specific characteristics of some of the waste would depend entirely on the types and quantities of non-stockpile CWM items to be processed and treated. However, based upon the estimated waste quantities discussed in Section 3.1.10 and Table 3-13, it is estimated that the even under a large deploy ment, such as envisioned in Scenario 3, the quantity of wastes generated and needing off-site waste management would likely result in only a few waste shipments by truck per week on average.

The potential impact of waste transport truck traffic (in combination with delivery truck traffic discussed above) on local traffic and transportation would depend on the site-specific conditions, especially the type and quality of roads serving the installation or other property, the existing level of truck traffic, and the existing level of traffic congestion. At large installations with a moderate to high level of existing truck traffic and served by high-quality roads, the additional truck traffic generated by normal treatment operations would likely have little impact. At small installations or non-military properties not accustomed to much truck traffic or served by secondary or lower-grade roads, there could be minor to moderate impacts to local traffic and transportation facilities including increased congestion, noise, increased risk of accidents (with and without hazardous material involvement), and increased wear on road surfaces.

5.3.9 Cultural Resources

During normal treatment operations and support activities, potential impacts to cultural and historical resources, archeological sites, and Native American lands and sites begun during site preparation and setup (Section 5.2.9) would continue. Potential impacts could include (1) disturbance or damage of cultural, historic, or archeological resources and (2) disruption of Native American religious areas, sacred sites, rituals, and traditional hunting or fishing grounds. The likelihood of direct physical disturbance and destruction of cultural, historical, archeological, and Native American sites, structures, or other resources would be reduced during the operations phase since most of the activities that would directly disturb the ground or structures would have been completed during the site preparation and setup phase. New impacts during the operations phase could include indirect impacts caused as a result of noise and vibration, access restrictions, evacuation requirements, visual impairments, and normal and accidental emissions or releases associated with non-stockpile CWM activities.

Several of the suspected non-stockpile CWM locations are located near existing lands designated as Native American reservations. These lands and other historically and cultural important structures and sites could be indirectly impacted in a number of ways, including normal operating emissions, noise, and visual impairment. As previously indicated in Section 5.2, the expected normal emissions associated with the transportable chemical treatment systems are not anticipated to be of consequence, unless sites without locally available power are used. Where locally available power is not available or is insufficient to power the treatment systems, on-site generators would be used. Use of one or more electric generators would generate air emissions and noise that could impact nearby cultural, historic, or Native American areas. The magnitude of air emissions and noise would depend on the site-specific situation, but would be greater for the MMD systems and for multi-system deployments. The other primary source of air emissions and noise during normal operations would be from truck traffic to and from the site and within the installation or other property boundaries. Such truck traffic could also generate ground vibrations that could affect nearby sites and structures. Except at sites without locally available power, most of the potential noise sources associated with the deployment of transportable chemical treatment systems would be temporary and infrequent. At sites with and without local power, noise generation could be reduced or eliminated during periods that would conflict with sensitive cultural or Native American ceremonies or other activities.

Within the controlled area, populations may be required to evacuate during daylight working hours when CWM is being moved or processed. Such evacuations could cause disturbances of culturally important activities in or near the controlled area.

As discussed in Section 5.2.9, the Army would endeavor to avoid or minimize disturbances and damage to culturally important, historic, and archeological resources and Native American lands to the extent possible by following the appropriate state and federal protocols and through consultations with affected parties. In every case, it may not be possible to avoid adverse

impacts. The potential for such disturbances or damages would be considered along with other factors in the site selection process. Prior to any site preparation activities, consultations with appropriate federal agencies, Native American groups and representatives, and State Historic Preservation Offices would be conducted to identify potential sites and activities of concern and mitigation measures necessary to avoid, reduce, or compensate for potential impacts.

5.3.10 Land Use

Land use impacts associated with the treatment site selection and deployment of transportable chemical treatment and support systems are discussed in Section 5.2.10. During the operation phase of a deployment these impacts would continue, including (1) potential conflicts with existing adjacent land uses, (2) conflicts with sensitive land uses, (3) delays in new uses of underlying or nearby lands, and (4) impacts on private lands.

New impacts specifically associated with treatment operations would primarily be related to the possible need to evacuate nearby residents or other persons within the controlled area surrounding the treatment site during CWM treatment operations or during accidents. When the land area required for the chemical treatment and support systems and the controlled area exceeds the size of a site or government-controlled property, evacuation of populations from their places of residence and work during daylight working hours could occur. Such evacuations could cause hardship on residents or businesses affected and would require careful coordination with local authorities. Depending on the extent and duration of the evacuations, either government acquisition of private property, compensation for evacuations, or temporary use of private property may be necessary.

In those instances in which non-stockpile CWM is located at large active military installations, it is not expected that evacuations would be necessary; however, a higher likelihood exists that such evacuations could occur at small military installations and at other properties which are no longer controlled by the DoD.

5.3.11 Socioeconomic Characteristics

Socioeconomic impacts of normal CWM treatment operations would largely be a continuation of those begun during the site setup phase (Section 5.2.11) and could include needs placed on existing community infrastructures and services by in-migrating workers (for example, increased need for housing); and increased demands placed on the use of emergency, hospital, and medical facilities and personnel. The types and levels of socioeconomic impacts that could be caused by non-stockpile CWM activities would be site-specific and would vary based on (1) the local demographic and geographic setting of the sites where activities would occur; (2) the number of systems deployed to a site, and (3) the duration of activities, which for non-stockpile CWM processing and treatment would predominantly be based on the types and amounts of non-stockpile CWM. Additional impacts during the normal operations phase could include controlled evacuations related to CWM handling and treatment activities.

As discussed in Section 3.1.2, a controlled area would be calculated based on an evaluation of potential accidents that could occur during CWM handling and treatment activities. Within the controlled area, populations could be required to leave their homes or places of work during daytime working hours when CWM would be moved or processed. This could vary from day to day depending on the risk determined for each day's operations.

Large military installations would likely be large enough to encompass both the site and controlled area. At locations with small land areas, which include small-sized military installations and other properties not under government control, a greater potential would exist for required evacuations. Evacuations of populations from their residences and from their places of work in the controlled area would have the potential for causing significant adverse socioeconomic impacts, including increased burdens on local police and fire departments and potential loss of income for persons or businesses within the controlled area.

At locations where in-migration of personnel would potentially burden existing community services or where controlled evacuations may be necessary, appropriate plans would be developed prior to initiation of site preparation and setup activities. These plans would assist communities in compensating for situations when existing resources may fall short of demand and may include provisions for hiring additional police officers, fire fighters, and emergency or medical personnel during the period when activities would be conducted.

5.3.12 Public Health and Safety

This section addresses public health and safety consequences that could result from the operation and pre-operational survey of the transportable treatment systems under normal operations. Under normal operations, the operation and pre-operational survey of the transportable treatment systems would take place as planned and designed without any accidental releases of hazardous substances such as chemical agent or treatment neutralent wastes. In addition, waste management activities at all waste management facilities—such as hazardous waste TSDFs, solid waste management facilities, wastewater treatment facilities, and recycling facilities—would also take place as planned and designed without any accidental releases of hazardous substances such as treatment neutralent wastes. Any non-accidental releases from waste management activities, such as discharges of treated wastewater following wastewater treatment, would be in accordance with permit limits. Public health and safety consequences that could result from accidental releases of hazardous substances are discussed in Section 6.

Emergency response plans would be prepared and implemented before any items containing chemical agent or industrial chemicals were handled, treated, or processed at the site. These emergency response plans are discussed in Sections 3 and 4.

5.3.12.1 Traffic Accidents

Under normal operations, the operation and pre-operational survey of the transportable treatment systems would generate additional truck and automobile traffic on roads in the

vicinity of the treatment site. This could possibly result in a small increase in the number of traffic accidents on such roads. Under normal operations, these accidents would not release hazardous substances, such as neutralent wastes, industrial chemicals, or treatment reagents. Any potential increase in traffic accidents would be site-specific and would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

5.3.12.2 Waste Management

Under normal operations, any non-accidental releases from waste management activities would be in accordance with permit limits. Such releases would not be expected to result in any adverse public health and safety consequences. The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated by the operation and pre-operational survey of the transportable treatment system. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

The NSCMP has in place a program of auditing and review of TSDFs that treat NSCMP wastes. This program would apply to TSDFs that accept and treat wastes from the transportable treatment systems. In selecting a specific, permitted, commercial TSDF to receive Army wastes, the Army would consider the past compliance history of the facility and the type of monitoring and pollution control equipment in use at the facility. The Army would also perform continuing assessments and audits of the performance of all hazardous waste TSDFs selected to ensure that these facilities remain in compliance with all applicable environmental regulations and safety requirements.

5.3.12.3 Health and Safety Effects on Children

Based on the environmental consequences discussed throughout Section 5.3, children would be unlikely to be exposed to disproportionate health or safety risks from the operation and pre-operational survey of the transportable treatment systems (Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks). This would be verified in the site-specific environmental analyses and documentation that would be prepared for each site.

5.3.13 Environmental Justice

Potential environmental justice impacts begun during site preparation and setup would continue during the conduct of normal operations. Potential impacts could include (1) lost economic opportunity, if new developments choose not to locate in areas in which non-stockpile CWM treatment and processing operations occur; (2) lower property values; (3) potential evacuation impacts; (4) an increase in the potential for human health and safety

impacts; and (5) postponement of economic redevelopment of the treatment site at closed military installations and other properties.

Potential impacts would be site-specific and would greatly depend on three specific factors: (1) the specific location of minority and low-income populations in relation to a site that would be used for non-stockpile CWM storage, processing and treatment; (2) the potential for atmospheric releases or other conditions (for example, air emissions or noise) that could impact minority and low-income population areas; and (3) the duration of the non-stockpile CWM storage, processing, and treatment operations. In most situations, the impacts associated with non-stockpile CWM would not extend beyond the military installation or property on which sites would be selected for non-stockpile CWM processing and treatment operations.

As discussed in Section 3.1.2, a controlled area would be calculated based on an evaluation of potential accidents that could occur during CWM handling and treatment activities. Within the controlled area, populations could be evacuated during periods when CWM would be moved or treated. All populations in such a situation could be adversely impacted, and to the extent that a significant portion of those affected were minority or low- income families, disproportionate adverse impacts could occur. Large military installations would likely be large enough to encompass both the site and controlled area. At locations with small land areas, which include small-sized military installations and other properties not under government control, a greater potential would exist for required evacuations. Evacuations of minority or low-income populations from their residences and from their places of work in the controlled area would have the potential for causing significant adverse socioeconomic impacts, including potential loss of income for persons or businesses within the controlled area.

Several mitigation measures (as discussed under other topics) could be implemented to avoid, reduce, or compensate for potential adverse impacts. These mitigation measures could also result in avoiding, reducing, or compensating for adverse impacts that could be experienced by affected minority and low-income populations. Site-specific analysis will be required to determine the most appropriate forms of mitigation.

5.4 Treatment System Closure and Demobilization and Site Closure

When treating and processing CWM items is completed at a site, the treatment systems would be decontaminated in accordance with permit requirements, cleaned, disassembled, packed for transport, and moved from the site. Site closure activities could include removing fencing and sediment runoff control devices, removing footings and foundations, remediating any soil contaminated during operations, disposing of any remaining wastes, and regrading and planting vegetation on the site as needed. Treatment system demobilization and site closure activities are described in Section 3.1.9.

5.4.1 Air Quality

Treatment site demobilization and closure would generate various air emissions at the site. The types and quantities of emissions generated would be site-specific and would depend on a variety of factors at the site. Major factors affecting emissions at a site would include the number and types of treatment systems to be closed and demobilized; the specific closure and demobilization activities conducted; the specific equipment and vehicles used; the time required for site demobilization and closure; the physical characteristics of the site; federal, state, and local air quality regulations applicable at the site; and the air pollution controls and mitigating measures that would be implemented at the site.

Air emissions generated would include criteria pollutants released by the operation of vehicles and equipment involved in site demobilization and closure activities and in the transport of personnel, equipment, materials, and closure-related wastes. Fugitive dust would be released by vehicles, equipment, and activities that disturb the ground surface, as well as by some other demobilization and closure related activities. HAPs could also be released by vehicles, equipment, and various closure-related activities such as solvent cleaning of equipment.

Air quality impacts from these emissions would be very site-specific. Major factors that would affect impacts include (1) the specific types and quantities of emissions that would be released, (2) existing air quality levels in the area, including the area's attainment status, (3) applicable federal, state, and local air quality regulations, including any state and local regulations that are in addition to, or more stringent than, the federal requirements, and (4) other local site-specific issues.

5.4.1.1 Potential Air Emission Sources

Air emissions could be emitted during site demobilization and closure by the following types of sources: fugitive dust-generating activities, diesel-powered generators, transportable treatment systems, mobile sources such as vehicles and heavy equipment, and miscellaneous demobilization and closure activities.

Fugitive Dust-Generating Activities. Various site demobilization and closure activities would generate particulates in the form of fugitive dust. Sources of fugitive dust would include any activities that physically disturb the ground surface at the site, such as any necessary removal of footings, foundations, environmental enclosures, buildings, and/or paved areas, as well as any related site grading activities. Fugitive dust could also be generated by debris handling activities at the site, including volume reduction and loading of debris into vehicles for transport to disposal locations. Personal vehicles, trucks, and heavy equipment would also generate fugitive dust when traveling over paved and unpaved roads. Fugitive dust could also be generated if site closure included any restoration of existing buildings at the site.

The amount of fugitive dust emissions generated would be very site-specific and would depend upon such factors as the amount of land disturbed, the specific activities conducted at the site and the timeframe over which they are conducted, the number and types of vehicles

and other mobile equipment used at the site, the vehicle-miles traveled on paved and unpaved roads, the dust suppression and other mitigating measures used at the site, and such local factors as wind speed and the silt and moisture content of site soils.

State and local regulations and military installation requirements could dictate controls, such as covering trucks hauling debris and other loose materials; applying water or other dust suppressants; or restricting activities on days with unfavorable meteorological conditions. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

Diesel-Powered Generators. Diesel-powered generators could be used at various sites to generate electrical power during site closure and demobilization, either as the primary source of power or as an emergency backup (see Section 5.4.7). When used, diesel-powered generators would emit criteria pollutants and small quantities of some HAPs as discussed in Section 5.2.1.1. Emission quantities would be site-specific, would depend upon such factors as the hours of operation and the amount of power generated, and are discussed in Section 5.3.1.1. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

Transportable Treatment Systems. The transportable treatment systems would be decontaminated, cleaned, disassembled, packed for transport, and moved from the site as part of site closure and demobilization activities. As previously discussed, treatment and unpack systems would be placed in trailers or other environmental enclosures under negative air pressure to ensure that any gases that would be released during the operational phase would only be released from an exhaust stack after passing through redundant carbon filter elements. Near real-time monitors would be strategically located to ensure that no agent or other chemicals used in the systems would be emitted. Decontamination and cleaning of the transportable treatment systems would occur under similar conditions and would not be expected to release air pollutants to the atmosphere.

Any treatment reagents, neutralents and other wastes, and industrial chemicals remaining at the site would be transported from the site during demobilization and closure. These reagents, wastes, and chemicals could contain some substances that are included on the Clean Air Act list of HAPs or that are subject to the Chemical Accident Prevention Provisions of the Clean Air Act (see Section 5.3.1.1). Most of these substances would be present only in very low concentrations and would not be expected to be released to the atmosphere.

Mobile Sources. Mobile sources of emissions would include trucks, personal vehicles, and heavy equipment used at the site. Trucks would be used to transport heavy equipment and closure-related materials to the site; to transport closure-related wastes and heavy equipment from the site; and possibly to transport the treatment system itself from the site. Personal vehicles would be used to transport workers to and from the site. The heavy

equipment used would depend on the specific closure and demobilization activities carried out and could include graders, bulldozers, forklifts, and similar equipment.

The mobile sources would release criteria pollutants. Emission quantities would be site specific and would depend upon such factors as the vehicle-miles traveled by the cars and trucks and the total number of hours that heavy equipment is operated.

Miscellaneous Sources. Various other closure and demobilization activities, such as solvent cleaning and equipment maintenance, would produce small amounts of solvent-based emissions that could include both HAPs and other volatile organic compounds. These emissions would be extremely site-specific and would depend on the activities conducted, the materials used, and the timeframe over which they are used. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

5.4.1.2 Air Quality Impacts

Air quality impacts from site closure and demobilization would be extremely site specific and would depend upon such factors as the specific types and quantities of air pollutants emitted, existing air quality in the area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts would have to be in compliance with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented during site closure and demobilization as necessary.

All necessary air quality reviews, permits, and approvals would be obtained as discussed in Sections 5.2.1.2 and 5.3.1.2. The need for additional controls and mitigating measures would be identified and implemented based on these reviews, permits, and approvals.

5.4.2 Noise

Noise would be generated by system closure and demobilization and site closure activities. Noise sources could include operation of equipment during treatment system cleaning, disassembly, and packing; truck transport of any remaining wastes to approved disposal, treatment, and recycling facilities; transport of the transportable chemical treatment and support systems away from the site; and operation of construction equipment to remove foundations and regrade the site. Noise levels would likely be intermittent and would vary from hour-to-hour during normal work hours, depending on the site-specific activities undertaken. These sources of noise could potentially disturb nearby residents and terrestrial wildlife, the extent depending on the source of noise, the distance of potential noise receptors to the sources, and meteorological conditions.

Types of equipment that might be used could include heavy-duty trucks, graders, bulldozers, forklifts, and similar equipment. Such equipment can generate noise in the range of 67 dBA to 98 dBA at a distance of 50 feet from the source (Golden et al., 1979; U.S. Environmental

Protection Agency, 1972). The level of noise could be greater if several pieces of heavy equipment are operating simultaneously. Time-averaged noise levels for major construction sites typically range from about 77 dBA to about 89 dBA for an 8-hour workday, depending on the type and pace of construction activity. The type and scope of activities that would be conducted to close and demobilize any of the treatment systems would generally be similar to that which would occur during small- to medium-scale construction projects.

In general, noise generated during system closure and demobilization and site closure activities would be short-term and of limited duration. Activities would generally be limited to up to 60 to 90 days at most sites. Noise levels after normal work hours would be unaffected, since all site preparation and setup activities usually would be limited to normal work hours. In addition, since most sites would likely be located well away from populated areas for safety reasons, the level of noise reaching receptor locations would be greatly reduced from the levels at the treatment site. Where noise-sensitive receptors are close to the site or the site-generated noise is greater than expected, mitigation measures may need to be employed.

After site closure, all noise impacts would cease.

5.4.3 Geology, Minerals, and Soils

Soils would continue to be affected during the period of equipment demobilization and transport from the site. These impacts would include compaction and alterations to soil structure from activities at the site. Some additional compaction could occur from equipment operation needed to demobilize, disassemble, and transport trailers and support equipment from the site.

Site closure activities may include restoration of soils on the site. Several soil restoration activities could be implemented, if required. The site could be graded to original contours. Gravel, paved surfaces, foundations, footers, and fences could be removed. Tilling could be used to remediate compacted and other disturbed areas. Stockpiled topsoil could be spread back over the site.

The extent of soil restoration would be site specific and would depend on restoration requirements identified and agreed to during the site planning phase. The extent of soil restoration activities may depend on the use and disturbance of the site before treatment operations took place and proposed uses of the site after treatment operations are completed.

Soil samples would be analyzed for contaminants during the site closure process. Contaminants that were due to operation of the treatment system at the site would be remediated during site closure.

Economically important subsurface minerals under or near the site would probably remain inaccessible during site demobilization and site closure. It is unlikely that any activities during this phase would render these resources permanently inaccessible. When site closure is completed, economically important subsurface minerals should once again be accessible.

5.4.4 Groundwater

Groundwater resources should not be significantly affected by demobilization and closure activities. No groundwater wells would be operated at the site. Potable water would continue to be supplied by local utilities or provided in tanks filled from a water supply system elsewhere and transported to the site as needed. Domestic and uncontaminated wastewater would continue to be discharged to a local sanitary sewer system and treated at a wastewater treatment facility or collected in holding tanks and transported to a wastewater treatment facility off the site. Normal leaks of petroleum products from vehicles and equipment operating on the site should not be enough to pose a significant risk of groundwater contamination. Hazardous chemicals and wastes would be handled in containers according to the requirements of RCRA or CERCLA and would be removed from the site periodically.

Some or all of the previous groundwater recharge potential of the site, if any, could be restored during site closure. The extent of that recharge is restored would depend on the extent that previous conditions are restored at the site.

5.4.5 Ecological Environment

Effects on the ecological environment that occurred during site operation would continue during site demobilization and closure. Restoration of site ecological values during site closure would be site specific. The extent of restoration would be determined as part of site planning and may depend on previous site use and planned future site uses.

5.4.5.1 Upland Environment

Alterations to the upland environment, such as habitat loss, implemented during site preparation and operation would continue through site demolization and closure. Site closure activities may include restoration of the upland habitat on the site. Several restoration activities could be implemented, if required. The site could be graded to original contours. Gravel, paved surfaces, foundations, footers, and fences could be removed. Tilling could be used to remediate compacted and other disturbed areas. Stockpiled topsoil could be spread back over the site. Vegetation could be replanted.

The extent of restoration would be site specific and would depend on restoration requirements identified and agreed to during the site planning phase. The extent of restoration activities may depend on the use and disturbance of the site before treatment operations took place and proposed uses of the site after treatment operations are completed.

Soil samples would be analyzed for contaminants during the site closure process. Contaminants that were due to operation of the treatment system at the site would be remediated during site closure.

5.4.5.2 Wetland and Floodplain Environments

Alterations to wetland or floodplain environments implemented during site preparation and operation would continue through site demobilization and closure. Site closure activities may include restoration of wetland and floodplain area on the site.

Sediment in storm water runoff from the site could also affect adjacent wetlands. The amount of sediment in storm water runoff during site demobilization would likely be similar to that during site operation since site conditions would not be much different. There could be some small increase in sediment in runoff during site closure if extensive grading and ground-disturbing activities are part of closure activities.

Adverse effects are likely to be controlled to an acceptable level or eliminated by sediment control management measures that would be required by many states and local authorities and by all military installations during site demobilization and site closure. State, local, and/or installation authorities must approve a site sediment control plan before any activities begin at a site. Sediment control management measures would have been installed before site preparation activities commenced. Sediment control management measures must be continued during site demobilization and closure. Any sediment control measures in place must be inspected and kept in proper operating condition during the site demobilization and closure period.

Restoration of wetland area would be in accordance with the conditions of the permit issued by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act before site activities commenced. Permit conditions could require that any wetlands that had been filled or modified be restored as wetland area.

Restoration of floodplain area would be in accordance with the activities defined during site planning in accordance with Executive Order 11988, Floodplain Management.

Spills of hazardous chemicals and petroleum products handled on the site pose a potential threat to wetland and floodplain resources. These potential impacts are discussed in Section 6.

5.4.5.3 Aquatic Environment

Storm water runoff from the site into adjacent aquatic environments could contain some sediment and contaminants because of soil disturbances during site demobilization and closure and from leaks of fuel, oil, and lubricants. Domestic wastewater would also be generated on site.

Spills of chemical agent, hazardous chemicals, and petroleum products handled on the site pose a potential threat to groundwater resources. These potential impacts are discussed in Section 6.

Sediment and Contaminants in Runoff. Sediment and contaminants in storm water runoff from the site could affect aquatic environments adjacent to the site during site demobilization and closure. The amount of sediment in runoff would be site-specific but is likely to be small at any site. Adverse effects are likely to be controlled to an acceptable level

or eliminated by site sediment control management measures that would be required by many states and by all military installations. State, local, and/or installation authorities must approve a site sediment control plan before site preparation activities begin. Any sediment control measures in place must be inspected and kept in proper operating condition during the site operation period. The amount of sediment in storm water runoff during site demobilization would likely be similar to that during site operation since site conditions would not be much different. There could be some small increase in sediment in runoff during site closure if extensive grading and ground-disturbing activities are part of closure activities.

Storm water runoff could contain small quantities of hydrocarbon contaminants from normal leaks of fuel, oil, or lubricants from vehicles and equipment during site operation. The amount is likely to be small, and the amount in runoff would likely be typical of that from any other light industrial site of this size.

Domestic Wastewater. Domestic and other uncontaminated wastewater generated during site demobilization and closure would be discharged to a wastewater treatment system, which would usually discharge its effluent to surface waters. Site wastewater could be discharged directly to a wastewater system at the site or to portable domestic waste-collection systems brought to the site. Portable systems would be discharged to an off-site wastewater treatment system. These discharges would be regulated under the National Pollutant Discharge Elimination System permit issued to the wastewater treatment facility.

5.4.5.4 Threatened and Endangered Species

Any impacts on threatened and endangered species that occurred during site preparation and operation would likely continue during site demobilization and closure. These impacts would have been determined during site planning, and coordination with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service and with state agencies would have been completed during that phase. Impacts during site closure and demobilization would be site-specific and could include continuation of loss of habitat, reduced habitat quality, and effects on habitat use or reproductive success in adjacent areas. These impacts would continue for the period of site demobilization and closure of up to 90 days.

Site demobilization and closure would be carried out in accordance with any mitigating measures determined to be required in consultation with the responsible federal, tribal, and state agencies. These mitigating measures could include habitat restoration. The type and extent of site restoration would have been determined during consultation with federal and state agencies during the site-planning phase.

5.4.6 Waste Management

Treatment system closure and demobilization, along with site closure, would generate a variety of waste streams at each site (see Table 3-14 of Section 3). These waste streams could include: spent decontamination solutions and rinse waters; other decontamination and cleanup materials; filter elements; used personal protective equipment; laboratory wastes;

debris; trash and similar wastes; HVAC condensate; spent coolant/chiller fluids; sanitary waste; and spent oil and lubricants. While most of these waste streams would be generated from each of the four systems, the specific composition of many of the waste streams (e.g., spent decontamination solutions, spill cleanup material, filter elements) would be dependent upon the specific CWM being treated at the site.

As discussed in Section 3.1.10, all waste streams directly associated with agent would be sent to a permitted, commercial hazardous waste TSDF for management. Such waste streams would include some of the cleanup materials, filter elements, used personal protective equipment, laboratory wastes, and spent decontamination solutions and rinse waters. All these waste streams would be sampled and analyzed in accordance with RCRA requirements.

The remaining waste streams would be tested for the presence of chemical agent. Any waste stream identified as having agent present would be decontaminated, analyzed in accordance with RCRA requirements, and then sent to a permitted, commercial hazardous waste TSDF for management. The rest of the waste streams would each be sampled and analyzed in accordance with RCRA requirements to determine if it is a RCRA hazardous waste or a solid (nonhazardous) waste. If it were a hazardous waste, it would be sent to a permitted, commercial hazardous waste TSDF. If not, it would be sent to a permitted solid waste management facility or a wastewater treatment facility, as appropriate to the waste stream. However, spent oils, lubricants, and spent chiller/coolant fluids would be sent to appropriate recycling facilities. Some sanitary waste and some liquid waste could be discharged directly to a sanitary sewer system rather than being containerized and transported to a wastewater treatment facility.

The environmental consequences of managing those wastes that could be discharged to a sanitary sewer system or transported to a wastewater treatment facility are discussed in Section 5.4.7.2. Such wastes include sanitary wastes, as well as those rinse waters, spent decontamination solutions, liquid laboratory wastes, and HVAC condensates that are not RCRA hazardous wastes and/or associated with chemical agent. The management of all the other wastes is discussed below.

The specific facilities used to manage each waste stream would be determined on a site-specific basis and would depend upon the site-specific nature and composition of the waste stream. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process. The wastes would be managed in accordance with all federal, tribal, state, and local laws and regulations applicable at the treatment site and at the waste management facility. Compliance with these laws and regulations would be addressed in the site-specific analyses and documentation prepared for each site. Section 4.6 discusses the federal waste management regulations that would apply in managing the wastes at each type of facility.

The NSCMP has in place a program of auditing and review of TSDFs that treat NSCMP wastes. This program would apply to TSDFs that accept and treat wastes from the transportable treatment systems. In selecting a specific, permitted, commercial TSDF to receive Army wastes, the Army would consider the past compliance history of the facility and the type of monitoring and pollution control equipment in use at the facility. The Army would also perform continuing assessments and audits of the performance of all hazardous waste TSDFs selected to ensure that these facilities remain in compliance with all applicable environmental regulations and safety requirements.

The waste streams generated during treatment system closure and demobilization and site closure would be similar to many of the waste streams generated during the operation and pre-operational survey of the transportable treatment systems. However, no neutralents, repackaged industrial chemicals, bead blast residue, decontaminated munition casings, or other treatment process wastes would be generated. Furthermore, the annual quantity of demobilization and closure wastes generated under each of the four deployment scenarios described in Section 5.1 would be small compared to the annual quantity generated during the operation and pre-operational survey of the transportable treatment systems. As a result, the environmental consequences from managing the closure and demobilization wastes would be of a similar nature, but of a smaller magnitude, than those from managing the equivalent wastes generated during the operation and pre-operational survey of the transportable treatment systems. These environmental consequences are discussed in Section 5.3.6. Site-specific impacts would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

5.4.7 Utilities

Utility requirements and impacts during the system closure and demobilization and site closure phase would likely be very similar to those discussed in Section 5.3.7 for site preparation and site setup. During site demobilization, the electrical utility requirements would gradually ramp down and treatment and support systems were shutdown, cleaned, and packed for transport to the next site. Water and wastewater utility requirements would be related to system cleaning and decontamination operations in preparation for transport to a new site and to personnel drinking and sanitation needs of on-site personnel.

5.4.8 Traffic and Transportation

The principal transportation facilities used during system closure and demobilization and site closure would be highways and roads for transporting (1) the transportable chemical treatment and support systems, (2) solid and hazardous waste materials to approved disposal or treatment facilities, and (3) contractor personnel. In addition to roadways, sea, or rail modes of transport could be used to transport the transportable chemical treatment systems and support systems from to a site. The RRS and EDS are capable of being transported by military aircraft.

The impacts to local traffic and transportation systems would be site-specific and vary by local conditions and the characteristics of the actual deployment. However, potential impacts are described below in general terms as to types and general consequences.

Potential impacts to traffic and transportation would include increases in truck traffic on public roads and highways near the treatment site and increases in automobile traffic due to worker commuting.

5.4.8.1 Treatment System Closure and Demobilization

System closure and demobilization would involve the decontamination, disassembly, packing, and transport of the transportable chemical treatment and support systems to a new site. This process could take up to 90 days. Potential impacts to traffic and transportation would involve commuting by demobilization personnel, transport of wastes to approved TSDF or other facilities, and transport of the treatment and support systems to a new site.

Personnel for closing and demobilizing the transportable chemical treatment and support systems would be the provided by the operations contractor and would likely come from outside the area near the treatment site. Therefore, commuting by the demobilization personnel would continue the impacts discussed in Section 5.3.8.2. The number of personnel needed to demobilize the transportable chemical treatment and support systems under the scenarios described in Section 5.1 are presented in the table below. The number of personnel includes up to 20 people needed for support functions, such as administrative support, security, food service, and maintenance support. These support personnel would likely be local residents. The actual number of support personnel needed would vary by site and nature of deployment.

Scenario	Personnel	Commuter Trips Per Day
1	38	76
2	78	156
3	118	236

If the non-resident personnel are not housed on-site and each person commutes by private automobile each day, between 38 and 118 addition vehicle trips could be added to local traffic each morning and afternoon for up to 90 days. At the low end (Scenario 1), no impacts are likely. At the upper end (Scenario 3), the additional traffic could have some adverse effects on local traffic especially near entrances to the military installation or other property. Whether or not this has a significant impact on local traffic patterns would depend on the existing traffic conditions near the site and would be require a site-specific analysis.

If the non-resident personnel were housed on site, up to 20 vehicle trips each morning and afternoon would still be added to traffic near the site as local support personnel commuted to the site. This amount of traffic would likely have no significant impact on local traffic.

Mitigation measures could include scheduling work hours to avoid peak local commuting times, routing worker traffic to avoid high traffic roads when possible and providing for road

improvements and traffic control equipment or personnel near the entrance to the treatment installation or property.

Once decontaminated, disassembled, and packed, the chemical treatment and support systems would be transported to the next site by the most appropriate mode of transport. The RRS and EDS are capable of being transported by all modes of transportation (that is, by road, rail, air, and water). The MMD systems and other support systems are capable of being transported by land (that is, by rail or road) and by water. If the transportable treatment and support systems were transported via air, water, or rail, they would likely be transported from the site to the airport, port, or railhead by truck transport.

The primary components of the transportable chemical treatment systems are enclosed in trailers that of various sizes that can be transported by truck. However, some of the trailers are larger than standard trailers or may exceed the weight limits for certain highways and roads, requiring special use permits in certain states. Careful route planning for the transport of the systems would be required in order to ensure that the movement of the systems do not exceed weight restrictions and cause damage to existing highways and roads. Reviews and evaluations would be performed to ensure that roadbeds and bridges could support the weight of the transportable chemical treatment and support systems. Alternative routes would be reviewed in order to minimize any needed upgrades of roads and bridges that may be required.

The estimated numbers of truck trips needed to transport the transportable chemical treatment systems away from a site are shown in the table below.

System	Estimated Number of Truck Loads	Estimated Number of Truck Trips*
RRS	6	12
MMD-1	15	30
MMD-2	20	40
EDS	3	6

* Includes trips of tractors to pick up trailers at sites.

Under the scenarios discussed in Section 5.1, the number of truck trips generated by the transport of the transportable chemical treatment and support systems away from a site could range between about 12 and 82. The movement of the transportable chemical treatment and support systems from a site could occur over a period of time ranging from a few days to a few weeks. The impact of such a movement on local traffic patterns would depend on local road and traffic conditions near the site. It is possible that such a movement could cause disruption of traffic, especially where severe congestion exists or in areas that do not normally experience significant truck traffic. However, because of the limited duration of the movement, no lasting impacts would likely occur.

5.4.8.2 Site Closure

After the transportable chemical treatment and support systems were removed from the site, site closure activities would be conducted. Site closure would require transport of some construction equipment to the site and transport of solid and, possibly, hazardous wastes from the site. Local worker commuting would also generate some addition traffic near the site. The amount of additional traffic generated would vary by site and would depend on the scope of site closure activities needed and the size of the deployment. At sites with no residual soil contamination, the level of traffic generated would be similar to that generated by small construction project. The primary work could involve demolition of footings and foundation pads, removal of gravel, removal of perimeter fencing, and re-grading of the land. In most cases, the potential increase in traffic would be short-term and no major changes in traffic patterns on public road would likely occur.

Site preparation personnel would be local workers and would not likely add to the overall level of commuter traffic in the area. However, worker commuting during site closure would generate some additional traffic near the site.

Potential waste streams that could be generated during system closure and demobilization and site closure are shown in Table 3-14. Disposal of these wastes would generate some additional truck trips on local roads and highways as the materials were transported to approved solid or hazardous waste disposal or treatment facilities. The volume of wastes to be transported would depend on site-specific factors, including specific closure activities required at the site and the system deployment scenario. At sites with no residual soil contamination, the amount of waste that would need to be transported would likely be equivalent to that generated by a small-scale construction project. If post-treatment soil sampling showed residual contamination from non-stockpile CWM treatment and processing, the source of contamination would be removed. This would generate additional truck trips, as the soil would be transported to a TSDF for disposal or treatment.

Mitigation measures for reducing potential impacts to transportation resources, particularly those associated with impacts to roads and highways during system closure and demobilization and site closure would include the scheduling of shipments to avoid disruptions to local traffic, avoidance of roads and highways that are congested, scheduling of work hours to avoid peak commuting hours, and compensation for improvements to local traffic safety measures (for example, traffic signals and signs) and personnel, when necessary.

5.4.9 Cultural Resources

Treatment system closure and demobilization and site closure activities could continue cultural impacts begun with site preparation and setup (Section 5.2.9). Potential impacts to cultural and historical resources, archeological sites, and Native American lands and religious sites could include (1) disturbance or damage of cultural, historic, or archeological resources and (2) disruption of Native American religious areas, sacred sites, rituals, and

traditional hunting or fishing grounds. New impacts could occur if additional disturbance to the ground were required. Impacts would be similar in character to those of the site preparation and system setup phase.

Direct impacts could occur during the site closure activities if construction equipment needed to be brought in to remove foundation pads and footings, remove gravel, and regrade the site. The likelihood of direct physical disturbance and destruction of cultural, historical, archeological, and Native American sites, structures, or other resources would be less than during the site preparation phase since most of the excavation activities that could directly disturb the ground or structures would have already occurred during the site preparation and setup phase. It is unlikely that any new ground areas would need to be disturbed. However, if new groundbreaking were necessary, additional surveys and studies, if needed, would be undertaken to minimize the potential for damaging or disturbing cultural, historic, archeological, or Native American artifacts and sites.

Indirect impacts during the site demobilization and closure phase could be caused as a result of noise and vibration as trucks would visit and leave the site to move the transportable chemical treatment and support systems to another site and to transport debris and wastes to approved facilities for treatment or disposal. Some noise and vibration could also be generated at the treatment site during site closure if the use of heavy construction equipment were needed to remove foundations and regrade the site. However, these activities would likely be of infrequent and of limited duration. Noise generation could be reduced or eliminated during periods that would conflict with sensitive cultural or Native American ceremonies or other activities.

As discussed in Section 5.2.9, the Army would endeavor to avoid or minimize disturbances to culturally important, historic, and archeological resources and Native American lands to the extent possible by following the appropriate state and federal protocols and through consultations with affected parties. In every case, it may not be possible to avoid adverse impacts. Prior to any site preparation activities, consultations with appropriate federal agencies, Native American groups and representatives, and State Historic Preservation Offices would be conducted to identify potential sites and activities of concern and mitigation measures necessary to avoid, reduce, or compensate for potential impacts.

5.4.10 Land Use

During the site demobilization and closure phase of a deployment, land use impacts begun during site preparation and setup would continue but would likely be greatly reduced. Much of the risk associated with the treatment operation would be gone. Untreated CWM would not be present, however, it is possible that treatment wastes and/or repackaged industrial chemicals would remain in storage at the site awaiting transport and disposal. Also, if soil testing reveal contamination requiring cleanup, impacts would continue until the site was decontaminated.

Once the site were closed, it is likely that no lasting land use impacts would remain.

5.4.11 Socioeconomic Characteristics

Socioeconomic impacts of treatment system closure and demobilization and site closure would be a continuation of impacts of site setup and normal treatment operations (Sections 5.2.11 and 5.3.11) and could include needs placed on existing community infrastructures and services by in-migrating workers (for example, increased need for housing); and increased demands placed on the use of emergency, hospital, and medical facilities and personnel. Unlike normal operations, however, CWM would no longer be processed and the controlled area would likely be much smaller or eliminated, greatly reducing any impacts from controlled evacuations. The types and levels of socioeconomic impacts would be site-specific and would vary based on (1) the local demographic and geographic setting of the sites where activities would occur, (2) the number of systems deployed to a site, and (3) the duration of treatment system closure and demobilization and site closure activities.

5.4.11.1 Treatment System Closure and Demobilization

While the treatment systems remain on-site, the socioeconomic impacts would be the same as those caused by system setup activities. The system closure and demobilization personnel would be the same number and types as during site setup. Many of these workers would be the same as those who conducted the CWM treatment operations. They would continue to live in motels or apartments rented by the contractor in the local area or in temporary housing in mobile quarters moved to the area for this purpose.

Because CWM would no longer be processed, the controlled area would likely be much smaller or eliminated. Controlled evacuations would likely no longer be required, eliminating adverse socioeconomic impacts such as loss of income or increased burdens on local fire, police, and other safety authorities.

Once the treatment systems were demobilized and transported to another site, most, if not all, on-site personnel would depart. Most of the socioeconomic impacts related to the treatment operations would then cease.

5.4.11.2 Site Closure

During the site closure phase, most of the work would be conducted by local contractors using local labor. Since these workers would come from the regional community surrounding the site, it is likely that that they would have little or no net impact on the socioeconomic characteristics of the area, except for the benefit provided by the inflow of funds to procure local labor, materials, and services to support the site closure activities

Upon completion of site closure, all socioeconomic impacts would cease.

5.4.12 Public Health and Safety

This section addresses public health and safety consequences that could result from closure and demobilization activities under normal operations. Under normal operations, the closure and demobilization activities of the transportable treatment systems would take place as planned

and designed without any accidental releases of hazardous substances such as chemical agent or treatment neutralent wastes. In addition, waste management activities at all waste management facilities—such as hazardous waste TSDFs, solid waste management facilities, wastewater treatment facilities, and recycling facilities—would also take place as planned and designed without any accidental releases of hazardous substances such as treatment neutralent wastes. Any non-accidental releases from waste management activities, such as discharges of treated wastewater following wastewater treatment, would be in accordance with permit limits. Public health and safety consequences that could result from accidental releases of hazardous substances are discussed in Section 6.

Emergency response plans would be prepared and implemented before any items containing chemical agent or industrial chemicals were handled, treated, or processed at the site. These emergency response plans are discussed in Sections 3 and 4.

5.4.12.1 Fugitive Dust

Closure and demobilization activities that disturb the ground surface would generate fugitive dust emissions that could drift offsite. Appropriate dust suppression measures would be carried out in accordance with all applicable federal, tribal, state, local, and military service regulations to minimize the potential public health consequences from the release of fugitive dust. At some sites, the ground surface could be contaminated as the result of past activities at the site. In such cases, additional mitigating measures might be necessary. The need for mitigating measures would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

5.4.12.2 Traffic Accidents

Under normal operations, closure and demobilization activities would generate additional truck and automobile traffic on roads in the vicinity of the treatment site. This could possibly result in a small increase in the number of traffic accidents on such roads. Under normal operations, these accidents would not release hazardous substances, such as treatment reagents or spent decontamination solutions. Any potential increase in traffic accidents would be site-specific and would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

5.4.12.3 Waste Management

Under normal operations, any non-accidental releases from waste management activities would be in accordance with permit limits. Such releases would not be expected to result in any adverse public health and safety consequences. The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated by the closure and demobilization activities. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

The NSCMP has in place a program of auditing and review of TSDFs that treat NSCMP wastes. This program would apply to TSDFs that accept and treat wastes from the transportable treatment systems. In selecting a specific, permitted, commercial TSDF to receive Army wastes, the Army would consider the past compliance history of the facility and the type of monitoring and pollution control equipment in use at the facility. The Army would also perform continuing assessments and audits of the performance of all hazardous waste TSDFs selected to ensure that these facilities remain in compliance with all applicable environmental regulations and safety requirements.

5.4.12.4 Health and Safety Effects on Children

Based on the environmental consequences discussed throughout Section 5.3, children would be unlikely to be exposed to disproportionate health or safety risks from closure and demobilization activities (Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks). This would be verified in the site-specific environmental analyses and documentation that would be prepared for each site.

5.4.13 Environmental Justice

Potential environmental justice impacts begun during site preparation and setup would continue during the system closure and demobilization and site closure period. Potential ongoing impacts could include (1) lost economic opportunity, if new developments choose not to locate in areas in which non-stockpile CWM treatment and processing operations occur; (2) lower property values; and (3) postponement of economic redevelopment of the treatment site at closed military installations and other properties.

Much of the risk associated with the treatment operation would be gone. Untreated CWM would not be present, however, it is possible that treatment wastes and/or repackaged industrial chemicals would remain in storage at the site awaiting transport and disposal. Also, if soil testing reveal contamination requiring cleanup, land use-related impacts would continue until the site was decontaminated.

Once the site were closed, it is likely that no lasting environmental justice impacts would remain.

5.5 Transport of Chemical Warfare Materiel to a Distant Treatment Location

If CWM items are to be treated at a location distant from the burial or storage site, the items must be transported by truck and/or aircraft from site where the items are stored or recovered to the site where the treatment system has been set up for operation. Section 3.1.6 describes activities carried out to transport CWM items to a distant treatment location. In most cases, it is likely that existing roads and transportation infrastructure would be adequate for the transportation operations required.

5.5.1 Air Quality

Transporting nonstockpile CWM to an off-property location for treatment would require the use of military trucks, helicopters, and/or fixed-wing aircraft, as well as such support facilities and equipment as helicopter pads and airfields, vehicle maintenance shops, and fuel storage tanks and pumping systems (see Section 3.1.6). Transport and support activities would generate various air emissions.

Transport vehicles would release criteria pollutants, such as particulates, nitrogen oxides, carbon monoxide, and hydrocarbons, as well as much smaller quantities of some hazardous air pollutants (U.S. Environmental Protection Agency, 1985). Trucks traveling over paved and unpaved roads would generate fugitive dust, as would winds created by the helicopters and aircraft during idling, takeoffs, and landings. Transport-related activities, such as vehicle maintenance and fueling, would also generate some HAPs and other volatile organic compounds.

The types and quantities of emissions generated would be site-specific. For most sites, the incremental increase in air emissions from these transport activities would be expected to be small compared to the air emissions generated by other life-cycle activities of the treatment systems. Major factors affecting transport-related emissions would include the mix of vehicles and aircraft used; distances traveled; number of landings and takeoffs; idling times on pads and runways; local factors such as the silt and moisture content of soils; applicable federal, state, and local air quality regulations; and air pollution controls and mitigating measures implemented.

Air quality impacts from these emissions would be extremely site specific and would depend upon such factors as the specific types and quantities of air pollutants emitted, existing air quality in an area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts would have to be in compliance with applicable federal, state, tribal, and local laws and regulations, as well as military installation requirements. Appropriate site-specific controls and mitigating measures would be implemented as necessary. Such measures might include applying water and other dust suppressants, cleaning pads and runways, and restricting transport activities on days in which air quality is poorer than normal. Any mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process (see Section 5.2.1.2).

5.5.2 Noise

Noise generated during the transport of non-stockpile CWM to an off-site treatment location would be caused primarily by the transport trucks or aircraft. Transporting non-stockpile CWM by air is the preferred method for transporting CWM other than for short ground moves that would be accomplished by truck. Transporting non-stockpile CWM by air as described in Section 3 would typically involve helicopter and/or fixed-wing aircraft.

Transport of non-stockpile CWM by road would also not be expected to measurably increase noise levels, except when a large and continuous number of truck shipments would occur along routes in rural or other normally quiet areas. Transport by fixed-wing aircraft and helicopters to and from existing airfields would also not be expected to result in any major increase in the noise already present. Helicopter transport of non-stockpile CWM from or near a site with non-stockpile CWM, and to or near a treatment location, could introduce a new source of noise in those areas if new takeoff and landing facilities are built. Although the absolute level of noise from a helicopter is about one-half of those produced by jet transport aircraft, the throbbing of blade slap and rotor rotational noise increase annoyance (Army Technical Manual 5-803-2). Noise levels produced by helicopters could exceed levels accepted in residential areas and those that are typically present in rural areas. In addition, because two sites would be involved (that is, the site where non-stockpile CWM is located, and the offsite location to which non-stockpile CWM would be transported) potential noise impacts could occur at both locations as well as along the transport route.

The number and frequency of movements of non-stockpile CWM would depend on site-specific factors including the number and type of CWM items, the pace of recovery operations, and the type of transportation mode used. In most cases, it is likely that the frequency of transport movements of non-stockpile CWM would be few and infrequent, limiting the potential for significant adverse noise impacts.

Several mitigation measures could be used to reduce the impacts of noise generated during offsite transport of non-stockpile CWM items. The identification of acceptable locations and/or sites for the helicopter landing and takeoff areas could consider the potential impact of noise and ensure that candidate sites are not in close proximity to sensitive receptors or facilities (such as schools, hospitals, retirement homes, or other long-term health care facilities). Both natural and man-made noise reduction barriers could be used. The scheduling of helicopter landings and takeoffs could be controlled to coincide with those times during the day that would minimize potential annoyance and disturbance. Takeoff and approach procedures could be designed to minimize the spread of noise. For truck transport operations, transport routes could be selected to avoid populated or other noise-sensitive areas.

5.5.3 Geology, Minerals, and Soils

Soils and economically important subsurface minerals would be affected during transport of non-CWM from a storage or recovery location to a treatment location only if new construction is required for roads to helicopter pads. All activities would be typical truck and/or aircraft operations similar to those that take place routinely for other reasons every day. Most transportation activities would take place on existing roads and airfields and within the existing commercial and military air transportation and air traffic control system.

5.5.4 Groundwater

There would be no significant effect on groundwater during transport of non-CWM from a storage or recovery location to an off-site treatment location. No new groundwater wells are likely to be required. No new ground-disturbing activities that could affect groundwater resources would likely be required since existing transportation infrastructure would likely be used for most sites. Normal leaks of petroleum products from transport vehicles and aircraft would not be significant enough to pose a threat to groundwater quality since the quantity would be extremely small, the vehicles would already be in use for other purposes, and the use to transport non-stockpile CWM would infrequent.

5.5.5 Ecological Environment

There would likely be no significant effect on the ecological environment or threatened and endangered species during transport of non-stockpile CWM from a storage or recovery location to an off-site treatment location. All activities would be typical truck and/or aircraft operations similar to those that take place routinely for other reasons every day. No new habitat is likely to be affected and no new disturbance factors would be introduced because most transportation activities would take place on existing roads and airfields and within the existing commercial and military air transportation and air traffic control system. Some habitat could be disturbed if new access roads or helicopter pads must be constructed. Activities occurring on active military installations would take place within the existing framework for endangered species management already in place at that installation.

5.5.6 Waste Management

Transport of CWM to a treatment location would likely generate two waste streams: trash and spent oil and lubricants. The trash would likely be combined and disposed with the trash generated at the treatment site. Spent oil and lubricants would most likely be generated when the transport vehicles were maintained at their normal maintenance locations and would be managed in accordance with the standard procedures at those locations. The environmental consequences from managing both of these waste streams would be of a similar nature, but of a smaller magnitude, than those discussed for these same types of waste streams in Section 5.3.6.

5.5.7 Utilities

Transport of non-stockpile CWM to an off-site treatment location would have little or no impact on local utilities. The only requirements for utilities related to the transport of CWM would be (1) water supply and wastewater disposal for those personnel loading or unloading the non-stockpile CWM on trucks or aircraft and (2) electrical power for security systems at the IHF on the installation or other property where the non-stockpile CWM items were recovered. It is likely that water supply and wastewater disposal would be provided by portable systems. The amount of electrical power needed for security systems would be

relatively minor and would be provided by a local electrical power supply system, if available. If an onsite source of local electrical power supply were unavailable, an onsite generating system would be required.

5.5.8 Traffic and Transportation

As discussed in Section 1.6, the National Defense Authorization Act for Fiscal Year 1995 (Public Law 103-337) placed restrictions on the movement of chemical agents and munitions. These restrictions prevent moving non-stockpile CWM out of the state where it is located, unless being moved to the nearest CWM stockpile storage facility that has permits for receiving and storing such munitions and agents. The Secretary of Defense must consider the movement necessary and can only take place if public health and safety is protected adequately during the transportation.

As discussed in Section 3.1.6, air and road transportation modes could be utilized for the transport of the non-stockpile CWM. The method of transporting non-stockpile CWM to an off-property treatment location would be by air other than for short ground moves. Typically, non-stockpile CWM would be transported by truck to either a helicopter pad or a suitable airfield. The helicopter or aircraft would fly to a helicopter pad or airfield near the treatment location where it would be transferred to the IHF or existing storage facility by truck. The shipment of the non-stockpile CWM items to the treatment location by air would be accompanied by military escort personnel. Emergency response personnel would not accompany the shipment but would be placed on standby during the transport by air. Limitations imposed on a transportation operation could include limiting speed of the transport vehicle to less than 40 kilometers (25 miles) per hour, changing routes to avoid congested areas, or limiting the number of trips made (Department of the Army, 1997a).

All transportation activities would be conducted in compliance with USDOT, state, and military transportation requirements. Prior to the transport of any non-stockpile CWM to an offsite location, a route-specific transportation plan would be developed by the NSCMP for all aspects of the transport. This plan would require the approval of the Army and would be submitted to the U.S. Department of Health and Human Services for review and recommendations. Transportation-related activities that would be addressed in these plans would include packaging, manifesting, monitoring, mode of transport, routes, emergency response, and a site-specific and route-specific hazard analysis. In addition, prior to the transport of non-stockpile CWM, there would be Congressional and state notification of the transport as required. Non-stockpile CWM items would be transported in containers meeting USDOT specifications and would be transported in accordance with hazardous material transportation routing criteria and regulations pursuant to the Hazardous Materials Transportation Act.

The potential impacts of non-stockpile CWM transport on local traffic and transportation would depend on the site-specific conditions, including the type and amount of CWM to be

transported, the existing level of local traffic, and the existing level of traffic congestion. Relatively small movements of material would likely cause no impacts. Large movements could lead to more significant impacts, including increased traffic congestion, noise from trucks, and increased risk of accidents (with and without hazardous material involvement). Also, the transport of non-stockpile CWM to a treatment location could require establishing a transport infrastructure at both the sending and receiving sites. The transport infrastructure at both sites could include the construction of new or modification of existing access roads, and the preparation of safe helicopter landing areas or construction of helicopter pads.

The potential impacts of air movement of non-stockpile CWM would include (1) noise from helicopters or other military aircraft and (2) increased risk of transportation accidents (with or without CWM material involvement) along the route.

5.5.9 Cultural Resources

Transport could potentially affect cultural and historical resources, archeological sites, and Native American lands and religious sites. Potential impacts could include (1) disturbance or damage of cultural, historic, or archeological resources and (2) disruption of Native American religious areas, sacred sites, rituals, and traditional hunting or fishing grounds.

Impacts related to the transport of non-stockpile CWM from the discovery site to an off-site treatment location could be caused by noise, vibration, and air emissions from transport trucks and military aircraft moving non-stockpile CWM items to an off-site treatment location. The truck trips would impact areas in the vicinity of the discovery site and/or the treatment location since trucks would only be used for short ground moves to a nearby location or to an aircraft landing area. The extent of such impacts would be site-specific and would depend on the proximity of culturally important resources or lands to the transport routes, the sensitivity of the resources to transport-related impacts, and the amount of non-stockpile CWM to be moved.

Additional impacts could occur if interim storage facilities, access roads, or aircraft landing areas would need to be constructed. The transport of non-stockpile CWM to a treatment location could require establishing a transport infrastructure at both the sending and receiving sites. Also, approximately 1 acre (0.4 hectares) of land at a site with non-stockpile CWM could be required for the interim storage of non-stockpile CWM until it could be transported to a treatment location. Construction of new storage or transportation facilities could directly disturb or destroy historical, archeological, or Native American sites, artifacts, or other resources through excavation and other activities.

Prior to undertaking site preparation activities, site-specific consultations, research, and field surveys would be performed to identify whether the siting of any of the facilities or infrastructure would affect historic or cultural resources. Consultations with appropriate federal agencies and State Historic Preservation Offices would be conducted. Additionally, Native American groups and representatives would be contacted to determine potential

Native American concerns with the direct use of land, and land that could be indirectly impacted by non-stockpile CWM activities.

As discussed in Section 5.2.9, disturbances to culturally important, historic, and archeological resources and Native American lands would be minimized to the extent possible by following the appropriate state and federal protocols and through consultations with affected parties. In every case, it may not be possible to avoid adverse impacts. Prior to any non-stockpile transport activities, consultations with appropriate federal agencies, Native American groups and representatives, and State Historic Preservation Offices would be conducted to identify potential sites and activities of concern and mitigation measures necessary to avoid, reduce, or compensate for potential impacts. Mitigation measures could include selection of transport routes or locations for transportation infrastructure to avoid sensitive areas and scheduling non-stockpile CWM movements to avoid periods that would conflict with sensitive cultural or Native American ceremonies or other activities.

5.5.10 Land Use

The transport of non-stockpile CWM could create land use conflicts in addition to those associated with the treatment location discussed in Section 5.2.10 for treatment site operations. These potential additional conflicts could include use of additional land to construct helicopter landing areas, noise from the landing and takeoff of helicopters that would be used in transporting non-stockpile CWM, and impacts to land uses along the transport route, including potential evacuations along the transport route in the event of an accident. While the use of helicopters would only occur temporarily, these activities could disrupt normal adjacent or nearby land use activities and could conflict with land uses such as schools where helicopter noise would be incompatible. In most cases, these potential additional conflicts would most likely occur on and around non-stockpile CWM locations that were located on smaller military installation or properties no longer owned by the military. Transport accidents could occur anywhere along the route. However, as a mitigation strategy, routes would be analyzed and selected to minimize risks to the public.

5.5.11 Socioeconomic Characteristics

The potential impacts associated with the transport of non-stockpile CWM would be related primarily with controlled evacuations that could be needed during normal loading and unloading operations. Such evacuations of populations from their residences and from their places of work in the controlled area would have the potential for causing adverse socioeconomic impacts, including increased burdens on local police and fire departments and potential loss of income for persons or businesses within the controlled area.

The same potential evacuations that could occur around a treatment location with non-stockpile CWM, could also occur if the CWM items were transported offsite. Even though the

CWM would be treated at a distant location, interim storage of non-stockpile CWM at a site before it would be transported would still require the establishment of a controlled area.

As discussed in Section 3.1.2, a controlled area would be calculated based on an evaluation of potential accidents that could occur during CWM storage and handling activities. Within the controlled area, populations could be required to leave their residences or places of work during periods when CWM would be moved or in the event of an accident. Large military installations would likely be large enough to encompass both the site and controlled area. At locations with small land areas, which include small-sized military installations and other properties not under government control, a greater potential would exist for required evacuations. Evacuations of populations from their residences and from their places of work in the controlled area would have the potential for causing significant adverse socioeconomic impacts, including increased burdens on local police and fire departments and potential loss of income for persons or businesses with the controlled area.

Also, the transport of non-stockpile CWM would require establishing a transport infrastructure at both the sending and receiving sites, as well as potential response to accidents resulting from transport of non-stockpile CWM. An increase in personnel beyond those needed for site preparation and setup activities would be required. Additional personnel associated with the transport of non-stockpile CWM would incrementally add to the total number of personnel required, but would not be expected to measurably change potential socioeconomic impacts to communities from those under the on-site treatment scenario.

Measures to reduce the potential for socioeconomic impacts would include careful planning of the transport operations to avoid and minimize the risk to the public along the transport route. All transportation activities would be conducted in compliance with USDOT, state, and military transportation requirements. Prior to the transport of any non-stockpile CWM, a route-specific transportation plan would be developed by the NSCMP for all aspects of the transport. This plan would require the approval of the Army and would be submitted to the U.S. Department of Health and Human Services for review and recommendations. Site-specific evaluations would address specific mitigation measures when a potential for adverse socioeconomic impacts could occur at a site or on a transport route.

5.5.12 Public Health and Safety

This section addresses public health and safety consequences that could result from the transport of CWM to an off-site treatment location under normal operations. Under normal operations, the transport of the CWM would take place without any accidental releases of hazardous substances such as chemical agent. In addition, waste management activities at all waste management facilities—such as solid waste management facilities and recycling facilities—would also take place as planned and designed without any accidental releases of hazardous substances such as treatment neutralent wastes. Any non-accidental releases from waste management activities would be in accordance with permit limits. Public health and

safety consequences that could result from accidental releases of hazardous substances are discussed in Section 6.

Emergency response plans, including a transportation emergency response plan, would be prepared and implemented before any items containing chemical agent or industrial chemicals were transported to the site or handled, treated, or processed at the site. These emergency response plans are discussed in Sections 3 and 4.

5.5.12.1 Traffic Accidents

Transport of CWM under normal conditions would generate additional truck traffic on roads in the vicinity of the treatment site. This could possibly result in a small increase in the number of traffic accidents on such roads. Under normal operations, these accidents would not release hazardous substances, such as chemical agents or industrial chemicals. Any potential increase in traffic accidents would be site-specific and would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

5.5.12.2 Waste Management

Under normal operations, any non-accidental releases from waste management activities would be in accordance with permit limits. Such releases would not be expected to result in any adverse public health and safety consequences. The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated by the transport of CWM to an off-site treatment location. The Army, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

5.5.12.3 Health and Safety Effects on Children

Based on the environmental consequences discussed throughout Section 5.5, children would be unlikely to be exposed to disproportionate health or safety risks from the transport of CWM to an off-site treatment location under normal operations (Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks). This would be verified in the site-specific environmental analyses and documentation that would be prepared for each site.

5.5.13 Environmental Justice

Minority and low-income populations could be affected by the transport of non-stockpile CWM from the recovery site to the distant treatment location. Non-stockpile CWM would be transported by truck to and from helicopter pads or safe landing areas. In most situations, the transport of non-stockpile CWM would not occur outside of military installation boundaries. To the extent, however, that such transport does occur outside of military installations, high concentrations of minority and low-income populations residing along and near roads and areas used for helicopters could be disproportionately impacted by noise, small increases in

truck traffic, potential restrictions on the use of roads during transport, and potential truck and helicopter accidents that could release chemical warfare agents or industrial chemicals.

Evaluation of potential impacts to minority and low-income communities along road transport routes and in proximity to potential helicopter landing areas would occur as part of route-specific planning prior to the selection of transportation routes. Environmental justice concerns would be evaluated along with other factors in selecting an appropriate route. In certain cases, impacts to minority and low-income populations may be unavoidable, as higher risks might be associated with the use of alternative routes.

5.6 Adverse Impacts that Cannot be Avoided

Treating and processing non-stockpile CWM items using transportable treatment systems at an operating site would have some adverse environmental and socioeconomic impacts that could not be avoided, even if mitigating measures were implemented. The extent of impacts would be site-specific and would depend on the activities conducted at a site. Unavoidable impacts would be modest or minor and within regulatory limits and would last only for the duration of operation at a site. Unavoidable impacts are described below.

Setup and operation of treatment systems would require use of from one to six acres of land until operations were completed and the treatment systems were decontaminated and removed from the site. During this time, the site would be mostly unavailable as wildlife habitat. Soils could be affected permanently if not restored during site closure. Sediment in runoff from the site could increase some during site preparation and site closure. Access to economically important minerals under or near the treatment site could be eliminated or restricted.

Operation of vehicles, equipment, and generators (if needed) at the treatment site and aircraft for transporting CWM to a distant treatment location would generate noise and release pollutants into the air.

Hazardous and other solid and liquid wastes would be generated that would require treatment and disposal.

Use of the operating site for other activities would be precluded for the duration of treatment operations. Use and/or access restrictions could be placed on adjacent properties while CWM items are being processed and treated.

People living and working in areas adjacent to the operating site could have to leave their homes or places of work on some days for safety purposes while CWM were being processed or transported.

5.7 Irreversible and Irretrievable Commitments of Resources

Operating transportable treatment systems to process and treat non-stockpile CWM would result in some commitment of resources that would be irreversible and irretrievable. These would be energy, chemicals and materials, landfill capacity, and economic and human resources.

Energy in the form of fuels and electricity used directly or indirectly to operate the treatment systems and associated vehicles and support systems would be an irretrievable commitment of these nonrenewable resources. This energy would be unavailable for other uses.

Various chemicals and materials would be required to operate the transportable treatment systems and support facilities and equipment. Chemicals and materials that would not be recycled or reused would be irreversibly committed to this activity because most wastes from treatment operations would be disposed of permanently in landfills or by other permanent destruction methods as required under RCRA, CERCLA, and other federal, tribal, state, and local statutes and regulations.

Placing solid and hazardous wastes generated from treatment operations in solid and hazardous waste landfills would have the practical effect of irreversibly committing this landfill space to wastes from this activity. This space would be unavailable for wastes from other sources.

Capital, workers, and equipment used for treating and processing and/or transporting non-stockpile CWM would be and irreversible commitment of these resources to this activity, making them unavailable for other purposes. Capital would be committed permanently. The commitment of equipment and workers' time would be only for the duration of the time it takes to locate and treat all non-stockpile CWM.

5.8 Relationship Between Short-Term Uses of Man's Environment and the Maintenance and Enhancement of Long-Term Productivity

Using transportable treatment systems to process and treat non-stockpile CWM would require the short-term use of land area and environmental impacts until treatment operations were completed at a site. This short-term use of land and the occurrence of impacts would permanently eliminate potential future risks to human health and safety and the environment from the buried and stored CWM that were treated and processed at the site. After the short-term use of an operating site was competed and CWM were removed from a burial site, the sites could be returned to other uses and long-term productivity.

Disposal of wastes generated from treatment sites in landfills would result in a long-term commitment of land with restricted surface and possibly subsurface uses. This commitment would be accompanied by the permanent elimination of potential future risks to human health and safety and the environment from the buried and stored CWM that were treated and processed at the site and the restoration of these lands to other productive uses.

5.9 Cumulative Impacts

Various other ongoing or future planned actions could occur in the vicinity of any site used to treat CWM in a transportable treatment system and/or any site used to manage wastes generated from the transportable treatment system. The nature and impacts of these other actions would be very site-specific. The cumulative impacts of normal treatment system operations and the impacts of these other actions would also be very site-specific. These cumulative impacts would be considered in the additional site-specific environmental reviews conducted by the appropriate DoD authority when a decision is to be made about how and where to process and treat non-stockpile CWM stored or buried at a specific site.

The only cumulative impact from normal operations that can be quantified on a national basis relates to the volume of waste generated from the transportable treatment systems. The volume of waste estimated to be generated annually would represent an insignificant increase in the total volume of waste currently managed nationwide at each relevant type of waste management facility (see Sections 5.2.6, 5.3.6, 5.4.6, and 5.5.6). Impacts to local waste management facility capacities would be site-specific, however, and would be addressed in the site-specific environmental reviews that would be prepared for each site.

Section 6

Environmental Consequences of Accidentally Releasing Hazardous Substances

There would be a low probability of accidentally releasing hazardous substances at a treatment site; during transport of CWM items, treatment wastes, or treatment chemicals; or at a TSDF that receives neutralent wastes or repackaged industrial chemicals. Even if a release were to occur, there are a number of factors that could reduce or eliminate the potential for effects on human health and safety and the environment. This section describes the factors that affect the likelihood of exposing the public and the environment to hazardous substances during operations at a treatment site, some immediate effects that could result if the public or the environment were exposed, and the factors that would be considered to determine what site-specific response would be required to prevent long-term health and environmental effects from the release.

The Army has conducted a programmatic accident risk assessment to determine what accidents could occur during the non-stockpile CWM treatment program and the likelihood that these accidents could occur. The results of these analyses are summarized in the subsections below. An explanation of the methodology and a description of the site types considered in the analyses is provided in Appendix D. Complete descriptions and results are given in the programmatic accident risk assessment report (Department of the Army, 1999b).

The environmental impacts discussed in this section are programmatic in nature, as discussed in Section 1.3. If the Army decides to implement the preferred alternative, site-specific safety and environmental impact analyses would be conducted in the future when a decision is to be made about treating and processing non-stockpile CWM buried or stored at a specific location.

Chemical warfare agents and industrial chemicals could also be released during the activities described in Section 1.9 that take place at non-stockpile CWM burial and storage sites prior to treating the items in a transportable treatment system. These environmental management activities are the responsibility of other DoD organizations (see Section 1.8) and are necessary to ensure public health and safety at those locations. These activities are independent of whether the proposed transportable treatment systems are deployed as proposed by the Army (Preferred Alternative; Section 3.1) or the Army decides to find and develop a different method or technology to treat non-stockpile CWM (No-Action Alternative; Section 3.2). These activities are not under the control of the NSCMP; are independent of the NSCMP activities; are subject to environmental review and analysis under RCRA, CERCLA, and other statutes and regulations; and require public comment and input in the decision-making process. Therefore, the environmental impacts of these activities are not analyzed in

this programmatic environmental impact statement because they will be considered as part of decisions made in these other programs.

6.1 Factors Affecting Exposure

This section discusses the likelihood of hazardous materials being accidentally released during the lifecycle activities of a transportable treatment system and the likelihood of human populations and the natural environment being exposed to any such release should it occur. As discussed in Section 6.1.1, the probability of such a release occurring would be very low. If a release were to occur, the likelihood of exposing human populations and the natural environment to hazardous substances in the release would be site- and substance-specific and would depend upon various factors such as those discussed in Section 6.1.2. For most substances, these factors would be expected to result in a very small probability of exposure in the event of an accidental release.

The discussion below focuses on identifying exposure factors common to the different types of hazardous materials—chemical warfare agents, industrial chemicals, neutralent wastes, treatment chemicals, and petroleum, oils, and lubricants—that are associated with the transportable treatment system life cycle. Exposure factors that are specific to the different types of hazardous materials are discussed in Sections 6.2 through 6.6.

6.1.1 Likelihood of Release

The Army has conducted an accident risk assessment to identify the potential risks to the general public should hazardous materials be accidentally released while transporting, handling, and treating CWM or while transporting treatment wastes (Department of the Army, 1999b). The accident risk assessment addressed the following hazardous materials: chemical warfare agents, industrial chemicals, and neutralent wastes from the treatment of the chemical warfare agents. As part of this effort, the Army identified accident events that could initiate the release of these three types of substances and determined the likelihood of such accidents occurring. The accident risk assessment is summarized in Appendix D.

Based on the accident risk assessment, the probability of any type of release of these substances would be very low. Releases could result from munitions-handling accidents (such as puncturing a container with a forklift), accidental detonations, or accidents occurring during transport. Far less likely are risks of releases resulting from external accident events such as an earthquake or a plane crash onto a treatment facility. Appendix D and Department of the Army (1999b) describe scenarios and probabilities of various types of releases.

Two types of hazardous materials were not addressed in the accident risk assessment—chemicals (reagents) used in the treatment process and fuel oil and other petroleum products used at the site. For reasons discussed in Section 6.5 (treatment chemicals) and Section 6.6 (petroleum, oil, and lubricants), the probability of any release of

these substances would also be very low since accident initiating events would be very similar to those already addressed in the accident risk assessment.

6.1.2 Likelihood of Exposure

If a release were to occur, the potential for human populations or the natural environment to be exposed to substances released would be site- and substance-specific and would depend upon the following factors, which are discussed in greater detail below:

- Location of release
- Mode of release
- Amount of material released
- Fate and transport characteristics of the materials released
- Response and cleanup following a release

For most substances, these factors would be expected to result in a very small probability of exposure in the event of an accidental release, as discussed below.

6.1.2.1 Location of Release

Releases, if they were to occur, could occur either on the treatment site or offsite during transport activities to or from the treatment site. Various factors would affect the likelihood of exposure in each case.

Treatment Site. The location of the treatment site would be a major factor affecting the potential for human populations and the environment to be exposed to substances in a release. Treatment system siting decisions would seek to minimize the potential for exposures to occur should there be a release at the treatment site. Factors that would be considered in the siting decision are discussed in Section 3.1. For example, the siting process would take into account the hazards that could be posed by deploying mobile treatment systems in vulnerable areas. Such areas would include those in close proximity to critical habitats, populations of threatened or endangered species, or near surface water bodies that could potentially become contaminated from site runoff. Vulnerable areas would also include those near residential, commercial, agricultural and other areas where people are likely to live or work; municipal water supplies; domestic drinking water wells; aquifer recharge areas; fruit and vegetable farms and gardens; and other areas where drinking water or foodstuffs can potentially be contaminated.

The siting decision would also identify mitigating measures that would be put into place to reduce or eliminate possible impacts on environments and human populations should there be a release. For example, a site-specific emergency planning zone would be established as discussed in Section 3.1. Controlled zones would be established on a site-specific basis such that if a release were to occur, it would be expected to be within the controlled zone. Emergency response is discussed further in Sections 6.1.2.5 and 6.7.

Transport Route. The potential for exposure from a release would be greater if a release were to occur along the transport route rather than at the treatment site. This would be the case because the release could occur at any point along the route, not just at a location specifically selected to minimize the potential for exposures.

A route-specific transportation plan would be prepared, as discussed in Section 3.1, before transporting CWM to an off-property treatment location. The plan would address such factors as the mode of transport, the transport route, packaging of the CWM, and emergency response should a release occur during transport. The plan would also incorporate an emergency planning zone similar in concept to that at the treatment site.

In addition, all hazardous materials would be packaged and transported in accordance with USDOT regulations and RCRA regulations as discussed in Section 4. These regulations provide the established approach for managing the transport of hazardous materials to ensure the protection of public health and the environment.

6.1.2.2 Mode of Release

The potential for a release to result in an exposure would also depend on the different ways by which the materials might be accidentally released. Accidental releases would occur in the form of either spills or explosive releases.

Any of the materials—chemical warfare agents, industrial chemicals, neutralent wastes, treatment chemicals, and petroleum oils, and lubricants—could be released via a spill. Spills could result during the handling of the material or from any activity at the treatment site that damaged or punctured a munition or a container holding the material. Spills could also be precipitated by external events at the treatment site, such as an earthquake or airplane crash into a storage area. Additionally, spills could occur during transport of munitions and other substances to or from the treatment site.

Spills resulting from transport accidents would also have a greater likelihood of being associated with a fire than spills occurring at a mobile treatment site. A fire would likely consume some portion of the material, but would also release combustion products, the identities of which may not always be known. A fire could increase the potential for any nearby natural environments or human populations to be exposed. The spilled material itself would, however, tend to be confined to a relatively small area and be subject to the same stringent requirements for cleanup as would apply to spills at the mobile treatment facility (see Section 6.1.2.7).

Explosive releases could result only from explosively configured munitions. Smaller projectiles are the only explosively configured munitions. The larger munitions were typically neither stored nor disposed of while explosively configured (see Appendix B). Furthermore, chemical munitions have relatively low explosive forces. Therefore, the probability of an accidental detonation of one munition causing others to detonate would be less than that for conventional high explosive-filled munitions.

A spill or an explosive release would each be "one-time" events, as opposed to a long-term or continual release (such as would occur from an outfall or industrial stack). The potential for environmental or human exposure from a single spill or explosive release would be much less than that from repeated or continuing releases.

The behavior of a released substance and the resulting potential for environmental or human exposure could differ depending upon the mode of release and, as discussed in Section 6.1.2.4, on the physical and chemical characteristics of the substance. For example, spills of non-volatile substances, such as mustard agents, would tend to remain in place at the point of release and not become airborne. In contrast, the explosive release of a non-volatile substance could produce an aerosol.

6.1.2.3 Amount of Material Released

The potential for an exposure would also depend on the amount of material released. The greater the amount of a substance released, the greater the potential for it to result in an exposure, all other things being equal.

The amount of any substance released by a spill or explosive release would be site- and substance-specific. The amount released would depend upon such factors as the nature of the release mechanism and the number and capacity of affected containers and/or munitions. Releases would be in the form of "one-time" events, as opposed to long term or continual releases.

6.1.2.4 Fate and Transport in the Environment

The potential for an exposure to occur following a release would also depend on the fate and transport characteristics of any substance released. Depending on its characteristics, a released substance may or may not be likely to migrate in the environment following a release. The likelihood of migration also depends on the environmental media (e.g., soil, sediment, water, or air) into which the substance is released or subsequently transported. The more mobile that a substance is in the environment, the more likely the chances of people or natural environments being exposed to it.

When released into the environment, substances tend to break down into other compounds (degradation products). The fate of a substance, including the rate at which it degrades and the specific compounds into which it can degrade, varies both by the characteristics of the substance and the characteristics of the environmental media into which it is released or transported. Following a release, substances that can be highly toxic, such as chemical warfare agents, eventually break down into substances that are less toxic. The more persistent a substance is in the environment, the more likely the chances of people or natural environments being exposed to it.

Sections 6.2 through 6.6 discuss fate and transport characteristics for chemical warfare agents, industrial chemicals, neutralent wastes, treatment chemicals, and petroleum oils, and lubricants. Appendix F provides additional information on the physical-chemical

characteristics and the environmental fate of chemical warfare agents, industrial chemicals, treatment reagents, and neutralent wastes.

6.1.2.5 Response and Cleanup

Response and cleanup actions that would be carried out subsequent to a release would significantly reduce the potential for exposure.

Following a release, there would be an immediate response by the appropriate organizations in accordance with emergency response plans and procedures to help protect public health and safety and the environment. For releases at a treatment site, the Army would implement the site-specific emergency response plan, which could also include simultaneous response by other DoD organizations and by local and state authorities, depending on the circumstances of the release. First responders to a release during off-property transportation of CWM items by truck or aircraft would be the accompanying military personnel and local authorities until standby military emergency response personnel could arrive at the scene as quickly as possible. Transporters and local hazardous material response units, police, and fire departments would be the first responders to spills during highway transport of neutralent wastes and treatment chemicals in accordance with local plans for responding to hazardous material release incidents.

After completion of the immediate response, a site-specific investigation and evaluation would be conducted to determine any remedial action needed to ensure the long-term protection of human health and the environment from residual contamination that might still remain in the environment. The investigation would consider a number of factors and could involve a variety of activities that would depend on the circumstances of the release and characteristics of the area of the release.

Section 6.7 describes the laws, regulations, and guidance that determine and direct the response and cleanup activities; factors that could be considered in evaluating the potential for long-term threats to human health and the environment; and the activities that could be carried out to determine the nature and extent of the cleanup required.

6.2 Chemical Warfare Agents

Chemical warfare agents could be accidentally released with low probability at the treatment site or during transport to a distant treatment site. At the treatment site, releases could occur as spills during handling and processing, from an accidental detonation of an explosively configured munition, or from external events such as an earthquake or airplane crash into the site. An accident during off-property transportation could also release agent.

The risk associated with an accidental release of chemical agents at a treatment site or during transportation are discussed in Section 6.2.1. Factors that determine whether exposure to a release could occur are discussed in Section 6.2.2. The potential immediate ecological and human health effects that could occur if exposure takes place are described in Sections 6.2.3 and 6.2.4. Accident response and cleanup is discussed in Section 6.7.

Appendix E discusses the human health effects and Appendix F the environmental transformation and fate of chemical warfare agents. Information in these appendices is used in the following sections without reference. The appendices provide references to appropriate studies.

6.2.1 Risk of Accidental Release

The risks associated with the processing of non-stockpile CWM were characterized on a per-unit operation basis. The resultant risk rankings reflect both the frequency of an accident occurring and the consequences of the accident, and are presented in Table 6-1. A description of the methodology for the risk assessment process, an explanation of the site types, and a complete summary of the risk rankings for each unit operation and for each site-type is presented in Appendix D. The complete programmatic accident risk assessment is in Department of the Army (1999b).

6.2.1.1 Interim Storage

For interim storage, it was assumed that an IHF is used to provide temporary, safe, and secure storage. For this unit operation, the dominant contributor to risk would be a small aircraft crash into the IHF. Chemical agents could be released to the environment if the packaged CWM were damaged or detonated by the crash. The likelihood of occurrence for this accident was estimated to be in the extremely unlikely frequency category. For CAIS sites and for mustard sites with a large controlled area (site-types C and E), the risk would be low. However, the presence of sarin (GB)-filled munitions such as the 155-mm projectiles in site-type F or the ton container in site-type G could result in no-deaths and no-effects hazard distances of more than 10,000 meters. This placed the accident in severity category I, and the resultant risk group assignment is intermediate.

6.2.1.2 Transportation and Handling at a Treatment Site

The local ground transportation unit activity considers ground transportation and handling required to move CWM items from interim storage to an onsite treatment system; or ground transportation and handling required to move CWM items from interim storage to a military airfield for offsite transport. For handling operations, the dominant risk contributor would be accidental forklift tine puncture of an overpacked CWM or a ton container, resulting in an agent spill. Forklift accidents could result in agent release from only one CWM item at a time, as munitions would only be handled one at a time. The forklift accident frequency was estimated to be 1.0×10^{-5} per forklift operation. For sites with a single munition, the frequency category assignment was extremely unlikely (category C). However, for sites with multiple munitions, or if repeated handling steps would be required, the campaign frequency for that site could be raised to the unlikely level (category B). In either scenario, the resultant risk assignment is intermediate.

Table 6-1. Summary of Risk Group Assignments for Unit Operations for Chemical Agent

Controlled Area for Treatment System (meters)	Unit Operation				
	At Treatment Site			Transport to Treatment Location	
	Interim Storage in Portable Buildings	Transport and Handling[a]	Treatment	Transport and Handling[b]	Air Transport
Site-Type B, CAIS Only (CAIS with Mustard [HD])					
			RRS		
200	❍	❍	❍	❍	❍
1,000	❍	❍	❍	❍	
2,000	❍	❍	❍	❍	
Site-Type C, Non-Explosive Munitions (M70 bombs with Mustard[HD])					
			MMD-1		
200	□	□	□	□	□
1,000	□	□	❍	□	
2,000	❍	□	❍	□	
Site-Type E, Explosive Munitions (155-mm projectiles with Mustard [HD])					
			MMD-2 / EDS		
200	□	□	□ / □	□	
1,000	□	□	❍ / □	□	
2,000	❍	□	❍ / □	□	
Site-Type F, Explosive Munitions (155-mm projectiles with Sarin [GB])					
			MMD-2 / EDS		
200	□	□	□ /	□	
1,000	□	□	□ /	□	
2,000	□	□	□ / □	□	
Site-Type G, Chemical Samples (Ton container with Sarin [GB])					
			MMD-2		
200	□	□	□	□	□
1,000	□	□	□	□	
2,000	□	□	□	□	
Site-Type H, Unsafe Munition (155-mm projectile with Sarin [GB])[f]					
			EDS		
200	NA	NA		NA	NA
1,000	NA	NA		NA	
2,000	NA	NA	□	NA	

– upper risk group □ – intermediate risk group ❍ – lower risk group.

[a] Transportation and handling between interim storage facility and treatment system.
[b] Transportation and handling between interim storage facility and military airfield by truck, and between destination military airfield and storage facility.
[c] Analyzed only for the treatment unit operation using the EDS. Munition unsafe to move to an MMD-2.

CAIS – Chemical agent identification set
EDS – Explosive Destruction System
mm – millimeter
MMD-2 – Munitions Management Device–Version Two
NA – Not applicable
RRS – Rapid Response System

6.2.1.3 Treatment

Treatment of agent was evaluated for each treatment system. The RRS option (site-type B) fell into the lower risk group. There would be no accident scenarios that could release agent outside of engineering controls unless there was complete failure of engineering controls. Earthquakes were judged to be the most likely cause of engineering control failure. The very low probability of these events, coupled with the relatively small no-effects distances, resulted in assignment to the lower risk group.

The MMD-1 was utilized for site-type C, which involved M70 bombs filled with mustard (HD). The dominant accident risk contributor was an earthquake that leads to a loss of engineering controls. If the control area could only be maintained at 200 meters, the accident falls into the intermediate risk category. When the control area could be extended to 1,000 meters or beyond, the operation falls into the lower risk category.

For the MMD-2, earthquake or tornado accidents were the dominant contributors to risk. The event could lead to the accidental detonation of a projectile in the MMD-2 where high-speed fragments from the exploding projectile could cause physical damage to the system. For mustard (HD) munitions such as the 155-mm mustard (HD) projectile, risk falls in the intermediate group only when the control area could be limited to 200 meters, otherwise it is in the lower risk group. Sarin (GB)-filled munitions fall in the intermediate risk group, regardless of the size of the control area. The intermediate risk ranking for site-type F was influenced by the relatively more severe consequences arising from the release of sarin (GB) as compared to the sulfur mustards (H, HD, HT). When processing bulk sarin (GB) items, similar results were found. The sarin (GB) ton container processing (site-type G) falls into the intermediate risk category regardless of the control area size.

The EDS was evaluated both as an emergency system for the treatment of explosively configured munitions that are determined to be unsafe for normal handling and transport, and as an alternative to the MMD-2 for the routine processing of safe-to-handle munitions. The major risk contributor for the EDS was the scenario where the operator drops an intact munition that results in detonation or agent spillage. For sarin (GB)-filled projectiles (site-types F and H), EDS treatment falls into the upper risk group when the control area was 200 or 1,000 meters and was reduced to the intermediate risk group if the control area was extended out to 2,000 meters. For mustard (HD)-filled munitions (site-type E), the risk is in the intermediate group for all three control areas.

6.2.1.4 Long-Distance Transport to a Treatment Location

The long-distance transportation of CWM by military aircraft included movement by (1) helicopter to a fixed-wing aircraft runway, (2) fixed-wing aircraft to a military airfield near the destination site, and (3) helicopter from this airfield to a landing site on or near the destination storage or treatment site. Certain accident scenarios involving transport of CWM by helicopter for site-types C, E, and F fall in the intermediate risk group. However, similar scenarios involving transport by fixed-wing aircraft accidents fall in the lower risk group. This

difference in risk groups was due to the higher historical accident rates for the assumed type of helicopter (UH-1). The air transportation operations are assigned to the lower risk group for site-type B, and to the intermediate risk group for site-types C and G. Site-types E and F fall in the upper risk group because they involved movement of larger numbers of CWM items.

6.2.2 Factors Affecting Exposure

Section 6.1 discusses the general factors that could determine whether humans or the environment would be exposed if a release occurs. For most of the chemical warfare agents, these factors would be expected to result in a very small probability of exposure in the event of an accidental release. However, the probability of exposure may be higher for the volatile chemical warfare agents, if an explosive release occurs, or if an accident occurs during transportation. These factors are discussed below.

6.2.2.1 Facility Siting

Facility siting decisions would take into account the hazards that could be posed by deploying mobile treatment systems in vulnerable areas. The siting decision would have considered the possible impacts on human heath and safety and the environment and have put in place mitigating procedures. These factors are discussed in Section 3.1, which describes the preferred alternative. Thus, the facility siting decision is the first step in eliminating or reducing exposures to human populations and the natural environment.

6.2.2.2 Mode of Release

The behavior of the agent and the resulting impact on human health or the environment can differ depending upon the mode of release. Two release scenarios are considered: a container rupture resulting in a spill of agent, and the explosive release of a munition resulting in dispersal of agent through the air. Both spills and explosive releases would be in the form of "one-time" releases, as opposed to long term or continual releases (such as would occur from an outfall or industrial stack). The possibility of either of these events occurring has been examined and is reported in the accident risk assessment (see Appendix D and Department of the Army, 1999b). Because of the low risk of an external event (such as an earthquake, tornado, or plane crash) initiating a release, it is not considered in this section.

Spills

Spills could occur during events such as a container rupture due to handling agent munitions or containers. Dropping the munition or container or puncturing the container with a forklift could also result in a spill of agent. Because of the secondary containment afforded by the mobile treatment systems, only spills occurring outside of these trailers are considered in this section. Any release from an accident that breached the containment of the treatment systems would likely be less than the release from the accidents examined here.

Spills could also occur during transport of munitions to a distant treatment location, should that prove necessary. The impacts on the environment of a release during transport

would be the same as those for a treatment location, although there would be no controlled areas around the release location, as is the case for a treatment site. Spills resulting from truck or aircraft accidents may also introduce a greater volume of contaminants into the environment than spills at the mobile treatment facility. The severity of the resulting impact would be similar, although the area affected would be greater as the amount of agent released increases. Spills resulting from accidents during transportation have a greater likelihood of being associated with a fire than spills occurring at the mobile treatment site. A fire would likely consume some portion of the material, but would also result in the release of combustion products, the identities of which may not always be known. The spill itself would be contained in a relatively small area and be subject to the same stringent requirements for cleanup as would apply to spills at the mobile treatment facility.

The extent to which a spill of CWM presents a threat of exposure is also dependent upon the nature of the agent released. For example, the mustard agents are oily liquids with low vapor pressures and high boiling points (see Appendix F for physical characteristics of chemical warfare agents). As a result, spills of these agents would remain on the ground at the point of release until the relatively slow fate processes begin to degrade the material to less toxic forms or until the material is subjected to physical transport or cleanup. The release of mustard via a spill would not likely result in dangerous concentrations in the air and would be unlikely to have a significant impact on the natural environment or public health. Any contamination resulting from spills would remain in the controlled area surrounding the treatment facilities until cleaned up per Army contingency plans and other applicable laws and regulations.

Lewisite, a vesicant with effects and properties similar to the mustards, has a higher vapor pressure and Henry's Law constant. As a result, it exhibits a higher volatility than the mustards. Spills of lewisite could result in airborne concentrations at which effects would be exerted. Both lewisite and the mustard agents were intended as contact and inhalation agents, but evaporation was rarely the mode of release when used as a weapon. Instead, these agents were dispersed explosively, releasing aerosols. Lewisite could pose a threat to downwind populations and natural environments if spilled, but concentrations in air would likely drop off rapidly with distance. The determination of the control zone at the mobile treatment system locations should take into account the potential for releases of lewisite and other substances to migrate beyond the immediate area of the release.

The nerve agent VX is also an oily liquid with a very low vapor pressure. It is not water soluble, and spills of the agent would tend to remain in place until fate processes degrade the material or until physically transported. As a result, VX would not be expected to have an impact on public health or the natural environment beyond the control zone surrounding the mobile treatment facilities. Furthermore, VX is highly unlikely to be encountered in non-stockpile CWM.

Sarin (GB), soman (GD), and tabun (GA) are volatile substances that would tend to evaporate when spilled. Sarin (GB) would exist almost entirely in the vapor phase; soman and

tabun are progressively less volatile. Spills of these substances would have the potential to impact human health and the natural environments beyond the area immediately surrounding the spill site. However, these more highly volatile chemical warfare agents (i.e., sarin, soman, tabun) would readily dissipate in the air. Thus, the threat posed by these substances after an accidental release would be limited to the immediate area of the release. The concentrations of these substances in the air would rapidly decrease downwind.

Explosive Releases

Explosive releases could only occur with smaller projectiles (see Section 6.1.2.2). Chemical munitions have relatively low explosive forces. Therefore, the probability that the accidental detonation of one munition would cause others nearby to detonate is less than that of conventional high explosive-filled munitions.

Lewisite and the nitrogen and sulfur mustard agents were typically deployed in explosive munitions, although they were not always stored in that manner. The accidental detonation of a munition containing one of these agents would result in different impacts than a spill of raw agent. The aerosols produced could represent significant inhalation hazards.

The greater volatility of sarin (GB), tabun (GA), and soman (GD) means that an explosive release would disperse the agents over greater areas and that the agent would remain airborne for longer times compared to spills on the ground. Depending upon the munition type, lethal effects could be exerted for a considerable distance downwind.

VX would not be an evaporative threat. However, its significant toxicity and the possibility of dispersing the substance via an explosive detonation mean that this substance could affect human health and the natural environment if released.

6.2.2.3 Likelihood of Release

The probability of any type of release occurring is very low. Releases could result from munitions handling accidents (such as puncturing a container with a forklift), accidental detonations, or accidents occurring during transport. Far less likely are risks of releases resulting from external events such as an earthquake or plane crash onto a storage facility. Appendix D and Department of the Army (1999b) describe scenarios and probabilities of various types of releases.

6.2.2.4 Amount of Release

The site types evaluated in the programmatic accident risk assessment considered seven situations comprising varying types of CWM and agent and varying numbers of containers. While these site types do not necessarily bound the total variety of sites that might be encountered, they can be considered typical of the type of sites for which mobile treatment systems could be deployed. The agents that these site types could contain include the vesicating agent distilled sulfur mustard (HD) or the nerve agent sarin (GB).

Based upon the site types described, the maximum release of mustard would be approximately 60 pounds, resulting from a release from the M70 bomb. Lewisite (L) is a blistering agent similar to mustard and was presumably configured in much the same manner. Sarin (GB) was stored in ton containers, the rupture of which could result in the release of a maximum of 1,600 pounds of agent into the environment. The maximum amount of agent in explosively configured devices is 11.7 pounds of mustard (HD) or 6.5 pounds of sarin (GB) in the 155-mm projectile. The majority of CWM items are expected to be projectiles with smaller amounts of agent contained within. Very few ton containers would likely be processed in the non-stockpile CWM program.

6.2.2.5 Response and Cleanup

If an accidental release occurs, emergency response plans would be implemented by the Army to clean up releases (Section 6.7). Federal laws require the Army to report, clean up, monitor, and remediate, if necessary, any releases of hazardous materials.

6.2.2.6 Fate in the Environment

If there is an accidental release of CWM to the environment, the fate and transport characteristics of the agent would be factors in determining the threat of exposure (see Appendix F). For instance, both sulfur and nitrogen mustard s are oily liquids, poorly soluble in water. Their low volatility and solubility would result in relative stability in the environment. Sulfur mustard (HD) would hydrolyze rapidly in water, but its low solubility would retard this mechanism. Furthermore, bulk sulfur mustard in water would tend to form polymeric coatings consisting of hydrolysis products (thiodiglycol), which could prevent further dissolution and hydrolysis.

The two release scenarios for mustard would present different fate mechanisms at work. A bulk release of mustard from the (non-explosively configured) M70 bomb would result in a greater amount of agent in the environment, but the cleanup process would be simpler because of the physical characteristics of the spill and the agent. The response to spills dictated by the emergency response plans should effectively remove the agent from the environment. On the other hand, an explosive release from detonation of a 155-mm projectile makes cleanup more difficult, and spreads agent over a larger area. Natural attenuation and removal processes, predominantly hydrolysis, would occur more rapidly in this instance, however.

Lewisite (L) is a blistering agent with toxic effects similar to those of the mustards. Lewisite (L) differs in its environmental fate, however. Arsenic is one of the primary components of lewisite (L), accounting for 36 percent of the agent by weight. Regardless of the fate mechanism at work, arsenic would remain in the environment as a result of a release of lewisite (L). As lewisite (L), the agent can retain its blistering effect for three years or more in soils under some circumstances, although hydrolysis in alkaline conditions can blunt those effects. In water, lewisite (L) is first converted to lewisite oxide and hydrogen chloride. The toxic trivalent arsenic of lewisite oxide is then converted to the less toxic pentavalent arsenic.

Because of the potential release of large quantities through the rupture of ton containers, sarin (GB) poses a different threat to the environment than does mustard (HD) or lewisite (L). Sarin (GB) is a colorless liquid that would form a dense vapor in air. Because it is miscible in water, it may be removed from the atmosphere by rainfall. In natural waters and soils, sarin (GB) would be expected to hydrolyze rapidly to relatively non-toxic components.

VX has a low vapor pressure and even if dispersed explosively would tend to form droplets and settle to the ground. VX would hydrolyze in water, but the process would be slower than in soils and at least one degradation product (s-[2-diisopropylaminoethyl] methylphosphonothioic acid—known as EA 2192) is also toxic and not as easily hydrolyzed (although data are uncertain at this time).

6.2.3 Immediate Ecological Effects

Chemical agents were designed to produce an acute effect. The accidental release of agent, especially an explosive release, could cause harm to components of the natural environment within the immediate area of the release or in areas affected by a plume of sufficient concentration.

The assessment of potential environmental effects resulting from the accidental release of chemical warfare agents would ideally be based on studies of all possible effects of the chemicals of concern on all of the species that might be found in affected environments. However, available information on the chemicals of concern is limited to a few species (mostly aquatic) with acute toxicity (usually death) as an endpoint. For chemical warfare agents, acute toxicity would be the primary concern, since the compounds are acutely toxic and most agents break down rapidly. Furthermore, for reasons discussed in the analysis of exposure, some of the chemical warfare agents would be unlikely to pose a significant threat to the environment since accidental releases would be confined to the controlled areas near the mobile treatment systems.

Strong vesicants (blistering agents), the sulfur and nitrogen mustards can be toxic via inhalation, ingestion, and upon eye or skin contact. Depending upon the degree of exposure, effects can range from skin irritations to severe damage, especially to eyes and lung tissues. Organisms, including plants, coming in contact with mustard would suffer immediate impacts, up to and including death.

Lewisite (L) is also a potentially lethal blistering agent, although its mode of action is slightly different from that of the mustards. Ingestion or inhalation of lewisite (L) could cause a variety of systemic effects, leading to such effects as damage to the upper respiratory tract, liver, intestines, and bone marrow. A study by Buswell et al. (1944) found lewisite to be far more toxic, in terms of fish mortality, than the sulfur or nitrogen mustards. The presence of dissolved lewisite (L) also inhibited the growth of aquatic plants, although the concentrations at which this occurred is above that that might be expected from any but the largest spills.

Sarin (GB) is a potentially lethal nerve agent that would likely exist almost entirely in the vapor phase in the atmosphere. The lethal effects on ecological receptors would be dependent upon atmospheric conditions at the time of release and distance to receptors. Wind speed and direction would be critical factors in determining the extent of impacts. Cloud cover would dictate the rate of photolysis and/or deposition via rainfall events. Within much of the release plume, lethal effects could be expected for most organisms if concentrations of agent are great enough.

Although the primary exposure route is inhalation, skin contact and ingestion of sarin (GB) can also produce systemic effects attributable to the anticholinesterase properties of the agent. The result would be an interference with neurotransmission, usually resulting in convulsions and death due to paralysis of the respiratory system. Low-level exposures could cause a wide variety of symptoms, but the concentration range for reversible signs versus death would be fairly narrow.

The expected mode of exposure to terrestrial organisms for a release of sarin (GB) would be inhalation, although toxicity data are limited. Sarin (GB) would be quite soluble in water and removal mechanisms can include both hydrolysis and volatilization. However, exposures to sarin (GB) could be cumulative, and extended exposures to even low concentrations could have a lethal effect, whereas limited exposures to higher concentrations might be tolerated.

Although VX would not be expected at any of the sites where the mobile treatment systems would be deployed, its extreme toxicity and toxic degradation products warrant its discussion. Significant impacts on ecological receptors could be expected from the release of VX to the environment if exposure occurs. Effects would be felt predominantly in the immediate area of the release, but the presence of toxic degradation products means that downstream receptors in aquatic environments might also be affected.

6.2.4 Immediate Human Health Effects

Chemical warfare agents and some of their environmental degradation components can be divided into two major groups, based on their major acute effects. These groups include vesicants (blistering agents) and neurotoxicants (nerve agents). The vesicants include sulfur mustards (H, HD, HT), nitrogen mustards (HN-1, HN-2, HN-3), lewisite (L), and 2 -chlorovinyl arsenous acid and lewisite oxide that are environmental degradation components of lewisite (L). The neurotoxicants include soman (GD), tabun (GA), sarin (GB), VX, and EA 2192, which is an environmental degradation component of VX. VX and EA 2192 are not likely to be encountered in the NSCMP.

The acute effects of toxic doses of the vesicants could include searing pain, photophobia (avoidance of light), tearing of the eyes, skin reddening, blistering, second or third degree burns and ulceration of the skin, conjunctivitis, inflammation of the iris and cornea, violent sneezing, coughing, inflammation of the upper respiratory tract, pulmonary edema, diarrhea, restlessness, weakness, and hemolytic anemia (anemia caused by the rupture of red blood

cells). Fatal doses of these substances could cause death by shock or bronchial pneumonia. Non-fatal doses could cause blindness and scarring.

The acute effects of toxic doses of the neurotoxicants may include muscle twitches, tremors, weakness, runny nose, sinus congestion, drooling, excessive sweating, tightness in the chest, difficulty breathing, miosis (contraction of the pupil) and visual effects, headache, nausea, vomiting, abdominal cramps, involuntary defecation and urination, excess salivation, giddiness, and difficulty thinking. Many of these effects would be reversible after non-fatal exposures. Fatal doses typically could cause convulsions, central nervous system depression, and respiratory failure.

The potential for acute human effects depends on factors such as the likelihood of release of a toxic substance, the persistence of the substance in the environment after a release, and the concentration of the substance in the environmental medium (e.g., soil, water, air) to which members of the general population may be exposed. The potential for acute effects also depends on the likelihood that acute exposure to the chemical at its concentration in the exposure medium would produce an acute effect. The medium of concern for potential acute human effects principally would be air. This is because the presence of a toxic substance in the air would be more likely to result in significant acute exposures and would potentially expose a greater number of people over a wider area than release of the substance to soil, groundwater, or other medium.

However, the chemical warfare agents are characteristically not highly persistent in the air (Appendix F and Department of the Army, 1999d). They could be expected to dissipate in the air, degrade in the air, and/or settle onto ground surfaces and break down rapidly to form intermediate and final environmental degradation components. These mechanisms would limit the potential area and time of exposure that may be associated with accidental release of chemical warfare agents at most sites.

The area over which the chemical warfare agents and breakdown products such as EA 2192 or 2-chlorovinyl arsenous acid/lewisite oxide mixture might spread after an accidental release, and the likelihood and duration of any subsequent acute exposures would be limited by the (1) dissipation and environmental breakdown of the chemical warfare agents in the air after a release, (2) deposition of these chemicals from the air onto ground surfaces, (3) environmental degradation of these chemicals and their intermediate environmental degradation components on the ground surfaces on which they are deposited or formed, and (4) emergency responses conducted in accordance with site-specific emergency response plans and federal, state, tribal, and local regulations.

6.3 Industrial Chemicals

Industrial chemicals could be accidentally released with low probability at the treatment site, during transport of a CWM item to a distant treatment site, or during transport of repackaged industrial chemicals to a TSDF. At the treatment site, releases could occur as

spills during handling and processing, from an accidental detonation of an explosively configured munition, or from external events such as an earthquake or airplane crash into the site. An accident during off-property transportation could also release industrial chemicals.

The risk associated with an accidental release of industrial chemicals at a treatment site or during transportation is discussed in Section 6.3.1. Factors that determine whether exposure to a release could occur are discussed in Section 6.3.2. The potential immediate ecological and human health effects that could occur if exposure takes place are described in Sections 6.3.3 and 6.3.4. Accident response and cleanup is discussed in Section 6.7.

Appendix E discusses the human health effects and Appendix F the environmental transformation and fate of industrial chemicals. Information in these appendices is used in the following sections without reference. The appendices provide references to appropriate studies.

6.3.1 Risk of Accidental Release

A variety of industrial chemicals could be found in recovered munitions. The industrial chemicals used in weapons were designed to act as choking, tearing, blood, vomiting, and incapacitating agents. The accident risk analysis focuses on phosgene as the industrial chemical of concern because it is highly volatile, heavier than air, and can create a toxic cloud under many situations. Phosgene also requires a lower dose to achieve significant health effects as compared to other industrial chemicals routinely used as fill for chemical munitions, such as hydrogen cyanide and cyanogen chloride. The risks associated with the processing of industrial chemicals are characterized on a per unit operation basis. The resultant risk rankings reflect both the frequency of an accident occurring and the consequences of the accident and are presented in Table 6-2. Appendix D provides a complete summary of the risk ranking determinations for each unit operation and for each site-type, as well as a discussion of the risk assessment methodology.

Industrial chemicals such as phosgene would not be treated in an RRS (site-type A). Instead, industrial chemicals would be repackaged and sent to a commercial TSDF. When CAIS ampoules unpacked in the RRS are identified as containing phosgene, they would be segregated, and placed into cardboard mailing tubes cushioned with cotton balls. The mailing tubes would then be placed into cans made of heavy cardboard, which would subsequently be filled with granulated vermiculite (which serves as a cushioning material as well as an absorbent). The can would then be passed out of the RRS for final packaging into a shipping container that meets USDOT standards. The handling and transportation (by truck) of the CAIS generally falls into the lower risk group. The exceptions to the lower risk designation are the interim storage activity (where an aircraft crash into an IHF could release all of the phosgene at one time), and the transportation and handling activity associated with offsite air transport (which would require several additional CAIS handling operations). The lower risk grouping is attributed to the low frequency for breaching CAIS items that are being transported in protective shipping containers.

Table 6-2. Summary of Risk Group Assignments for Unit Operations for Industrial Chemicals

Controlled Area for Treatment System (meters)	Unit Operation				
	At Treatment Site			Transport to Treatment Location	
	Interim Storage in Portable Buildings	Transport and Handling[a]	Treatment	Transport and Handling[b]	Air Transport
Site-Type A, CAIS Repackaged Only (CAIS with Phosgene [CG])					
			RRS		
200	□	❍	❍	□	❍
1,000	❍	❍	❍	□	
2,000	❍	❍	❍	□	
Site Type D, Non-Explosive Munitions (M78 bombs with Phosgene [CG])					
			MMD-2		
200	□	□	□	□	□
1,000	□	❍	□	❍	
2,000	□	❍	□	❍	

– upper risk group □ – intermediate risk group ❍ – lower risk group.

[a] Transportation and handling between interim storage facility and treatment system.
[b] Transportation and handling between interim storage facility and military airfield by truck, and between destination military airfield and storage facility.

CAIS – Chemical agent identification set
MMD-2 – Munitions Management Device–Version Two
RRS – Rapid Response System

For the phosgene-filled M78 bomb (site-type D), most storage, handling and treatment activities fall into the intermediate risk grouping. This is a result of external accidents such as earthquakes, or by handling accidents, which could have the capacity to release the contents of the munition into the atmosphere. Phosgene would evaporate very quickly, making containment of the spill very difficult once the munition has been breached.

6.3.2 Factors Affecting Exposure

Section 6.1 discusses the general factors that could determine whether humans or the environment would be exposed if a release were to occur. For most of the industrial chemicals, these factors would be expected to result in a very small probability of exposure in the event of an accidental release. However, the probability of exposure may be higher for volatile chemicals, for explosive releases, or for accidents during transportation.

The potential for release of and exposure to industrial chemicals would differ somewhat from the circumstances for chemical warfare agents discussed in Section 6.2 as a result of differences in the treatment process and the characteristics of the industrial chemicals. Phosgene is the only industrial chemical that would be chemically neutralized in some cases

in an MMD-1 or MMD-2. Because phosgene would be processed in a manner similar to the process for neutralizing chemical warfare agents, the probability of accidental releases of phosgene would be similar to that of the chemical warfare agents. The other industrial chemicals would be containerized and disposed in a manner consistent with well-established methods for these hazardous materials. The industrial chemicals would be transported and disposed in accordance with USDOT regulations and RCRA regulations. These regulations, including their provisions for monitoring and enforcement, provide the established approaches for managing the disposal of these substances so as to ensure the protection of public health and the environment.

Following a release, the potential for the exposure of people or the environment would depend on the fate and transport characteristics of the industrial chemicals released. Spills of non-volatile industrial chemicals, such as chloroacetophenone, adamsite, 3-quinuclidinyl benzilate, bromobenzyl cyanide, and nitrobenzene, would tend to remain in place until these substances are degraded to produce less toxic environmental degradation components, or until they were removed or disturbed. Thus, exposures to spilled non-volatile substances would not be likely outside of the controlled zones of the mobile treatment facilities, or controlled zones established after a spill during the transport of these substances. In contrast, the explosive release of non-volatile industrial chemicals would be expected to produce aerosols that could represent inhalation or contact threats at some distance from the point of release.

Spills of more volatile industrial chemicals and solvents—such as chloropicrin, benzene, chloroform, carbon tetrachloride, and chlorobenzene—could yield airborne concentrations high enough to cause injury on exposure. For this reason, spills of the volatile substances could pose airborne threats downwind of the spill. These substances might have the potential to migrate in the air at sufficiently large distances downwind to threaten people or environments located near the controlled zones. However, the decrease in the concentrations of these substances with distance from the controlled zones would be expected to substantially reduce the likelihood of exposure to toxic concentrations beyond these zones.

Similarly, the most volatile industrial chemicals, such as phosgene, cyanogen chloride and hydrogen cyanide, would readily dissipate in the air. Thus, the threat posed by these substances after an accidental release could be limited to the immediate area of the release. The concentrations of these substances in the air could rapidly decrease downwind.

6.3.3 Immediate Ecological Effects

Industrial chemicals were to be used primarily as irritants and incapacitating agents, although some are lethal at high concentrations. Industrial chemicals that might be encountered as chemical warfare materiel and their intended effect are listed in Table 1-3.

Should industrial chemicals be released to the environment via an accidental release, natural systems could exhibit a response. The severity of response would depend not only upon the acute toxicity of the industrial chemical, but also on its persistence, mode of

exposure, and breakdown products. Several industrial chemicals are examined in this section because they exhibit characteristics that suggest they could present the greatest hazard to the environment in the event of an accidental release. These chemicals have been selected because of the their toxicity, persistence, mode of exposure, or breakdown products. The industrial chemicals reviewed in this section are adamsite, phosgene, and hydrogen cyanide.

Adamsite is an arsenical compound which, even upon complete degradation, would result in arsenic compounds remaining in the environment if it is released. At typical temperatures and pressures, adamsite would be a solid with a very low vapor pressure and a high boiling point. Consequently, it is unlikely to be a significant hazard unless released via an accidental detonation. In that circumstance, the heat of the explosion would be sufficient to form an aerosol of the agent, which would eventually settle onto land and water surfaces. The compound would hydrolyze rapidly, although bulk adamsite would tend to form an oxide coating that can prevent further hydrolysis. Exposure to the aerosol could produce intense inflammation of the respiratory tract and sinuses. Death of exposed populations would be unlikely except in confined areas where ambient concentrations could be significant.

Phosgene is a colorless gas that would not be expected to persist in soil or water but that could be transported downwind considerable distances in the event of a release. Phosgene would be primarily a threat by inhalation, potentially causing significant damage to the throat and lungs, pulmonary edema, pneumonia, and respiratory failure. In water, phosgene typically would decompose almost immediately to form hydrochloric acid and carbon dioxide. As a result, the threat posed by an accidental release of phosgene would be limited to the immediate area of the release.

Hydrogen cyanide generally would be both more toxic and more persistent in the environment than cyanogen chloride (another related industrial chemical), although exposure to each could induce similar effects. Cyanide would irreversibly bind oxygen in the blood; acute exposures could cause rapid death. Even mild exposures could cause a variety of systemic effects. Hydrogen cyanide could be present as either a colorless gas or liquid. Releases of hydrogen cyanide at the location of the mobile treatment systems could result from the rupture of small vials in CAIS sets or burst munitions. The hazard to the environment would be related to the quantities that might be released. Because any release would be an instantaneous event, concentrations that might prove fatal to organisms in the area would dissipate quickly. In aquatic environments, the persistence of hydrogen cyanide could lead to lethal effects at low concentrations due to the extended exposure (e.g., Broderius et al., 1977). There is some indication that long-term exposure to cyanide could have deleterious effects on reproduction (Leduc et al., 1982).

6.3.4 Immediate Human Health Effects

Industrial chemicals were weaponized because of their irritant and incapacitating properties, among other factors, although some can be lethal at high concentrations. The

industrial chemicals can be divided into five major groups, based on their major acute human effects. These groups are tearing agents, vomiting agents, respiration inhibitors, choking agents, and central nervous system toxicants. A sixth group consists of substances used as chemical-agent simulants. A summary of the acute effects is presented in Table 6-3.

Tearing agents include bromobenzyl cyanide and chloroacetophenone. These substances are more commonly known as tear gas and mace, respectively. Adamsite is a vomiting agent. Chloropicrin and mixtures of chloroacetophenone, chloropicrin, and chloroform (CNS) can be categorized as both tearing and vomiting agents. Hydrogen cyanide is a respiration inhibitor. Choking agents include phosgene and diphosgene. Cyanogen chloride is both a respiration inhibitor and a choking agent. The chemical 3 -quinuclidinyl benzilate is a central nervous system toxicant. Chemical-agent simulants include triphosgene and "GA simulant," which consists of diethyl malonate mixed with benzonitrile and/or other substances.

The potential for acute human effects would depend on factors such as the likelihood of release of a toxic substance, the persistence of the substance in the environment after a release, and the concentration of the substance in the medium (e.g., soil, water, air) to which members of the general population may be exposed. The potential for acute effects would

Table 6-3. Acute Human Effects of Various Industrial Chemicals

Agent	Acute Effects
Tearing agents	Irritation of the eyes, skin, and upper respiratory tract, burning sensation and pain in the eyes, skin, mouth, throat, and chest, tearing of the eyes, and nausea. Exposure outdoors in open spaces would not be expected to cause severe illness or death. Indoor exposures to high concentrations relatively long periods can cause serious illness and can be fatal.
Vomiting agents	Nausea and vomiting, irritation of the eyes, skin, and respiratory tract, coughing, and tearing of the eyes. Outdoor exposure would not be expected to cause severe illness or death. Indoor exposures to high concentrations for relatively long periods can cause serious illness and can be fatal.
Respiration inhibitors	Dizziness, difficulty breathing, nausea, vomiting, and retching. These agents interfere with the ability of the tissues and organs of the body to use the oxygen supplied by the blood. Breathing and heart rates characteristically increase in an exposed person in an attempt to supply more oxygen to the tissues and organs. Fatal doses cause death by respiratory failure.
Choking agents	Chest pain, burning sensation in the throat, choking and coughing. High doses can cause death by pulmonary edema, cardiac failure, pneumonia, or respiratory failure.
Central nervous system toxicant	Deficits in memory, attention, comprehension, and problem-solving abilities. At higher doses, these substances can cause disorientation, delirium, hallucinations, and stupor.
Chemical-agent simulants	Irritation of the eyes, skin, and upper respiratory tract, and tearing of the eyes. High doses can cause death by pulmonary edema, convulsions, or respiratory failure.

also depend on the likelihood that acute exposure to the chemical at its concentration in the exposure medium would produce an acute effect. The medium of concern for potential acute human effects principally would be air. This is because the presence of a toxic substance in the air would be more likely to result in significant acute exposures and would potentially expose a greater number of people over a wider area than release of the substance to soil, groundwater, or other medium.

However, the industrial chemicals are characteristically not highly persistent in the air (Appendix F and Department of the Army, 1999d). They could be expected to dissipate in the air, degrade in the air, and/or settle on ground surfaces and break down rapidly to form intermediate and final environmental degradation components. These mechanisms would limit the potential area and time of exposure that may be associated with accidental release of industrial chemicals at most sites.

6.4 Neutralent Wastes

Treating chemical warfare agents and phosgene would produce liquid neutralent wastes that would be containerized and transported to a commercial TSDF. The composition of neutralent wastes that could be produced from treating chemical agents and phosgene is given in Tables 3-8 to 3-12. Neutralent wastes would be temporarily stored (not more than 90 days) at the treatment system site, then transported from the treatment site to a TSDF for additional treatment, if needed, and disposal.

The character of neutralent wastes would depend upon the treatment process being used and the type of chemical warfare materiel being processed. Section 3 of this report describes the operation of the mobile treatment systems, including the composition of the neutralent wastes generated from each system. These wastes would be significantly less acutely toxic than the chemical agents from which they were generated (ERDEC, 1997a–f). Because of their reduced toxicity characteristics, they would be handled and disposed of in a manner similar to other industrial hazardous wastes.

The results of the accident risk assessment for neutralent wastes is provided in Section 6.4.1. How the natural environment or people could be exposed to treatment wastes if accidentally released is discussed in Section 6.4.2. The potential immediate ecological and human health effects that could result if an accidental release occurs are discussed in Sections 6.4.3 and 6.4.4. How the potential for longer-term effects would be assessed and cleanup requirements determined are described in Section 6.7. Appendix F discusses the possible environmental transformation and fate of treatment wastes if released into the environment. Information in Appendix F is used in the following sections without reference. Appendix F provides references to appropriate studies.

6.4.1 Risk of Accidental Release

Risk associated with the transportation of neutralent wastes generated from treatment processes fall in the intermediate risk group for all types of treatment systems (see Appendix D). The risk characterizations take into account both the frequency and severity of accidents associated with these activities.

In general, there would be two categories of neutralent wastes: that from the RRS processing of CAIS (which contains significant amounts of chloroform, which is a volatile chemical), and that from the other portable treatment systems (non-volatile liquids). A complete summary of the risk-rankings for each unit operation and for each site type is presented in Appendix D.

6.4.1.1 Rapid Response System (RRS) Waste

Neutralization of mustard (HD)-filled CAIS within the RRS (site-type B) would generate about 30 gallons of neutralent waste, the major component of which would be chloroform (50 to 87 percent), which is volatile. There could be non-fatal health effects out to a distance of a few hundred meters if all of the chloroform were released. Consequently, the handling and transportation of treatment waste falls in the intermediate risk group because of exposure to chloroform in the event of a truck accident and waste tank rupture.

6.4.1.2 Other Neutralent System Wastes

For the handling and transport of neutralent waste drums from site-types C through G, accidents that involve a breach of the drums (either by forklift during handling, or in association with a truck accident) are in the intermediate risk group. The chemical composition of the neutralent waste would not pose a fatality risk, but there would be the potential for skin damage from contact with the liquid waste. The intermediate risk assignment is a result of the assumption that the thin drums containing the waste would not afford any significant protection from puncture in the event of a collision. For the other accident scenarios involving neutralent waste drums, the lower frequency estimates place these activities into the lower risk group.

Overall, the activity of handling and transporting industrial chemical CAIS or neutralent waste drums from the treatment site to the TSDF would not pose significant risk to the public. Most accidents associated with these activities fall into the lower risk group. Nearly all of those that fall into the intermediate risk group are associated with skin damage from immediate contact with the liquid waste, and would more likely present a risk to workers who are in the immediate vicinity of the accident site. However, the neutralent waste would not pose a fatality risk to workers or the public. The one exception would be an accident involving RRS waste, due to the potential for volatile chloroform exposure. Placing the 30-gallon RRS waste drum in a puncture-proof overpack would mitigate the truck accident scenario, resulting in a lower risk group designation.

6.4.2 Factors Affecting Exposure

Treatment wastes could be spilled at the treatment site or during transportation by truck to a TSDF. Exposure of natural environments or people beyond the controlled area at a treatment site or the area adjacent to a truck accident would depend on the amount spilled and the volatility of the waste. In general, most of the neutralent wastes produced would be non-volatile. The one exception would be waste from processing CAIS in the RRS. This would contain a large proportion of chloroform, which is a volatile chemical.

6.4.3 Immediate Ecological Effects

The threat posed to the environment by neutralent wastes could occur from spills located at the mobile treatment facility or from spills occurring during transport of the neutralent wastes from the mobile treatment facility to a TSDF for treatment and disposal.

6.4.3.1 Spills at the Treatment Site

Spills that might occur at the treatment site would have very little impact on the natural environment. The waste liquids would remain within the controlled environment of the mobile treatment facilities. Facility siting decisions would probably limit the opportunity to impact surface waters. Furthermore, Army and other DoD component cleanup procedures would comply with RCRA and CERCLA regulations mandating the cleanup of hazardous materials to levels that are protective of human health and the environment. Thus, spills of waste on the ground at the treatment site would be unlikely to have either acute or long-term impacts on the environment. Impacts on the surrounding environment could only result from environmental transport of the neutralent wastes via air or groundwater.

Air releases would be due to the evaporation of volatile compounds in the waste. The only volatile compound that occurs in any significant amount is chloroform. The accident risk assessment has shown that a maximum credible event for the release of chloroform is the sudden evaporation of approximately 30 gallons of chloroform. However, chloroform is so volatile it would remain in the atmosphere, eventually dissipating to concentrations below those that would cause an effect (Appendix F). No deposition to the ground is expected. Thus, while acute effects could occur with a sudden release of chloroform-containing wastes, no long-term effects would be expected.

Significant groundwater contamination and transport would be unlikely because of the limited volumes of wastes that would be spilled and because of the chemical characteristics of the waste. Because any spills that might occur would do so during handling operations, only a limited amount could be spilled at any one time. The characteristics of the waste are detailed in Appendix F. While many of the wastes would be miscible in water, they would degrade in soils and, if released to soils, would therefore be less likely to be available for transport to aquifers. Furthermore, the response in the event of a spill would be aimed at removing contaminated soils and evaluating and eliminating the potential for contamination of groundwater. However, the potential for groundwater contamination would be dependent

upon such factors as the depth to groundwater, the soil type, and the climate, and would be evaluated on a site-specific basis prior to the deployment of the mobile treatment systems.

6.4.3.2 Transportation Spills

In the case of wastes shipped to a TSDF, spills resulting from accidents could affect soils or aquatic systems, depending upon the type and location of the accident. In many regards, the potential impact to the environment would be the same as that of spills located at the mobile treatment facility. Contaminants would be confined to a relatively small area, which would be adjacent to roadways and subject to cleanup requirements. Immediate impacts would be felt only within the area of the spill. Long-term impacts to the environment would not be expected because of the small impact area, the site cleanup requirements, and the reduced hazard of the wastes compared to the agents (see following sections). Two characteristics of offsite spills would introduce differences in the potential impact to the environment, however. First, the volumes spilled may be greater during transportation, because an accident may have the potential to rupture more containers. Secondly, the site of the spill would not be under controlled access and may allow for spills to enter surface waters.

Spills resulting from truck accidents may introduce a greater volume of contaminants into the environment than spills at the mobile treatment facility. The severity of the resulting impact would be similar, although the area impacted would be greater as the amount of waste released increases. Spills resulting from accidents during transportation would have a greater likelihood of being associated with a fire than spills occurring at the mobile treatment site. A fire would likely consume some portion of the material, but would also result in the release of combustion products, the identities of which may not always be known. This could pose an immediate threat to nearby environmental targets, but the rapid dispersal of airborne contaminants means that long-term effects would not be expected. The spill itself would be contained in a relatively small area and be subject to the same stringent requirements for cleanup as applies to spills at the mobile treatment facility.

Spills of neutralent wastes into waterways adjacent to roads are the greatest threat posed by the transportation of neutralent wastes. The possibility of an accident occurring that breaches a waste container is based upon both the statistical frequency of such accidents and the number and length of trips. Based on these factors, the greatest risk is for wastes produced at site-type D (M78 bombs with phosgene), site-type C (M70 bombs with mustard) and site-type E (155-mm projectile with mustard). The calculated risks are 2.4×10^{-3} for the first site type and 2.1×10^{-4} for the other two site types, or approximately 1 in 500 and 1 in 5,000, respectively. The possibility that these accidents would occur in a manner that leads to contaminants entering surface waters cannot be calculated without knowing the route of the vehicles, but is postulated to be much less.

6.4.3.3 Potential Acute Effects from Neutralent Wastes

The composition of the neutralent wastes would depend upon the treatment process and the agent undergoing treatment. Very few data are available for most of the waste products

from the mobile treatment systems. Tables 3-9 through 3-12 give the waste composition for the MMD-1. The MMD-2 and the EDS are expected to use the same neutralization method as in the MMD-1. The reported waste characteristics are based on laboratory scale reactions of GB, VX, and HD with MEA and chemical analysis of the resulting reaction mixtures. The major component of the waste streams is MEA/water. Toxicological test results are also reported. The waste streams from destruction of all three agents were shown to be non-lethal to test animals (no deaths to test animals with the 14-day test limit set by USDOT in 49 CFR Parts 107, 171-180, and 390-397).

The waste resulting from sarin (GB) destruction and the waste from destruction of mustard (HD) and VX were determined to be non-poisonous by the inhalation route. Neutralized mustard (HD) waste was shown to be non-vesicating. However, the waste streams tested caused severe irreversible skin damage to test animals. The skin damage is attributed to MEA/water in the waste stream.

Table 3-8 gives the neutralent waste composition for the RRS. No toxicological and TCLP analyses have been performed on the RRS waste streams. However, analyses show that all chemical agents (HD, L, HN-1 and HN-3) were neutralized to levels below 50 ppm for lewisite, 5 ppm for HD, and 20 ppm for HN-1 and HN-3. The major component of the waste is chloroform (50 to 87 percent). Chloroform could produce an acute effect in the immediate vicinity of a spill, leading to death of species within the plume of evaporation of a large-quantity release. This effect would be limited to the point of release and downwind areas, with a plume size dependent upon the amount of material released.

6.4.4 Immediate Human Health Effects

As discussed above, normal operation of the mobile treatment facilities would generate wastes from the neutralization of chemical warfare agents and phosgene. The composition of the neutralent waste solutions would depend on the specific chemical warfare agent(s) neutralized at the site, and the process used to accomplish the neutralization.

Exposure to concentrated solutions of many of the neutralent waste chemicals could cause acute effects attributable primarily to local irritation of the tissues at the point of contact. For example, irritation of the eyes, skin, nose, throat, and/or mucous membranes could be expected from acute exposures to concentrated solutions or vapors of the following substances:

- 1,1,2,2-tetrachlorethane
- 1,1,2-trichloroethane
- 1,1-dichloroethane
- 1,2-dichloroethane
- Acetaldehyde
- Barium (soluble compounds)
- Benzene
- Ethanol
- Ethylene glycol (EG)
- Hexachlorobutadiene
- Hexachloroethane
- Mercury
- Methyl ethyl ketone (MEK)
- Monoethanolamine (MEA)

- Carbon tetrachloride
- Chloroacetaldehyde
- Chloroform
- Chromium III
- Cyclohexylamine (CHA).
- Dichlorodimethylhydantoin (unreacted)(DCDMH)
- Selenium
- Sodium hydroxide (NaOH)
- t-Butyl alcohol
- Tetrachloroethylene
- Trichloroethylene

Many of these irritants also have the potential to cause central nervous system effects (e.g., drowsiness, dizziness, mental dullness, confusion, incoordination, and fatigue), including:

- 1,1,2,2-tetrachlorethane
- 1,1,2-trichloroethane
- 1,1-dichloroethane
- 1,2-dichloroethane
- Acetaldehyde
- Barium (soluble compounds)
- Benzene
- Carbon tetrachloride
- Chloroform
- Chromium III
- Ethanol
- Ethylene glycol (EG)
- Mercury
- Methyl ethyl ketone (MEK)
- Monoethanolamine (MEA)
- t-Butyl alcohol
- Tetrachloroethylene
- Trichloroethylene

Vinyl chloride also has the potential to cause central nervous system effects. Further, benzene is a bone-marrow depressant that can cause leukemia. Chloroacetaldehyde could cause pulmonary edema.

In addition, acute exposures to relatively high concentrations of the following substances has been associated with liver and/or kidney damage:

- 1,1,2,2-tetrachlorethane
- 1,1,2-trichloroethane
- 1,1-dichloroethane
- 1,2-dichloroethane
- Acetaldehyde
- Carbon tetrachloride
- Chloroform
- Ethanol
- Hexachlorobutadiene
- Hexachloroethane
- Mercury
- Selenium
- Tetrachloroethylene
- Trichloroethylene
- Vinyl chloride

Of the remaining substances that may appear in the neutralent wastes, acute exposures to relatively high concentrations of the following can produce unique sets of acute effects:

- 2,4-Dinitrotoluene can cause liver, cardiovascular, and reproductive system effects.
- Inorganic arsenic can cause liver, kidney, lung, and lymphatic system effects, and gastrointestinal disturbances.

- Cadmium can cause proteinuria (abnormal appearance of protein in the urine) from kidney damage.
- Lead can cause gastrointestinal tract and central nervous system effects, including weakness, exhaustion, anorexia, abdominal pain, colic, anemia, tremor, and encephalopathy.
- Nickel can cause sensitization dermatitis and allergic asthma.
- Silver can cause discoloration of the skin and gastrointestinal disturbances.

In addition, cadmium, silver, nickel, lead, mercury, selenium, chromium, inorganic arsenic, benzene, carbon tetrachloride, acetaldehyde, and trichloroethylene have the potential to produce reproductive or developmental effects, which could be further evaluated in site-specific analyses.

The potential for neutralent waste chemicals to cause injury depends on both the probability of an accidental release of these substances and the likelihood of exposure after the release. Many of the chemicals that would be found in the neutralent waste solutions are commonly found in industrial hazardous wastes. Procedures for transporting these hazardous wastes are already well established, including standards for response to spills, by the USDOT, USEPA, and other agencies. Thus, the probability of accidental release of neutralent waste solutions during transport to a disposal facility would be no more than the probability of accidental release of other hazardous wastes routinely transported in the United States.

The probability of a release would be very small. Thus, the probability of exposure would be correspondingly very small. However, in the event of an accidental release, the likelihood of exposure would depend on the siting of the mobile treatment facility, the nature and quantity of the neutralent waste chemical, the ways by which the chemical might be released, the environmental fate and transport of the released neutralent waste chemical, and contingency plans developed to eliminate or reduce the potential for exposure. For most of the neutralent waste chemicals, these factors would be expected to result in a very small probability of exposure in the event of an accidental release. However, the probability of exposure may be higher for the volatile solvent chloroform.

6.5 Treatment Chemicals

Several chemicals (reagents) would be used to treat chemical warfare agent and phosgene in the neutralization process carried out in the transportable treatment systems. These chemicals are listed in Appendix C. The principal treatment chemicals and solvents are the following:

- Monoethanolamine (MEA)
- 1,3-dichloro-5,5 dimethylhydantoin (DCDMH)
- Sodium hydroxide
- Sodium hypochlorite
- T-butyl alcohol
- Chloroform

These chemicals would be transported by truck to the treatment site and stored for use in treatment. Any unused chemicals would be transported from the site when treating CWM items was completed.

The reagent chemicals used in the treatment processes would be standard industrial chemicals used in large quantities in industrial processes. Both t-butyl alcohol and MEA, for example, are considered high volume chemicals by the USEPA, which means that they are produced or imported into the United States in quantities exceeding one million pounds annually. Transport of the reagents to the mobile treatment sites would constitute only a small fraction of the amount of these compounds transported annually in the United States for a variety of uses. For example, 668 tank-car loads of MEA (about 8,000,000 gallons) were shipped by rail in the United States in 1997 (Williams, 1999). Procedures and regulations for safely transporting these chemicals are in place, as are standards for response to spills, through regulating agencies such as USDOT and USEPA.

The probability of a release is discussed in Section 6.5.1. The factors affecting exposure of the natural environment or people to treatment chemicals if released are discussed in Section 6.5.2. The immediate acute ecological and human health effects that could result if an accidental release occurs are discussed in Sections 6.5.3 and 6.5.4.

Appendix F provides information about the environmental transformation and fate of treatment chemicals. Information in Appendix F is used in the following sections without reference. The appendix provides references to appropriate studies.

6.5.1 Probability of an Accidental Release

The probability of an accident at a treatment site that releases treatment chemicals has not been analyzed, but would likely be similar to that for treatment wastes. The probability of a truck transportation accident releasing chemicals would about the same as the probability of accident during the transportation of treatment wastes.

6.5.2 Factors Affecting Exposure

Treatment chemicals could be released at treatment sites or along transportation routes to or from a treatment site. At a treatment site, treatment chemicals could be released by spilling during handling of containers or from an external event, such as an earthquake or aircraft crash into a treatment facility.

Most treatment chemicals are non-volatile and would not be an airborne threat. The solvents chloroform and t-butyl alcohol are volatile chemicals that could pose and an airborne threat.

6.5.3 Immediate Ecological Effects

Because the treatment chemicals would be caustic and the solvents could pose an inhalation hazard, releases of these substances through accidental spills could have an

immediate and acute impact. This effect would likely be limited to the area of the spill, or, in the case of chloroform, to the small transient plume area resulting from its evaporation.

Transport of the neutralizing chemicals beyond the immediate spill area would be unlikely. The potential for surface water contamination would have been considered during site selection, and appropriate mitigating measures instituted. Additionally, spills would be cleaned up, further preventing runoff that might affect surface waters or groundwater. The potential for groundwater contamination, which is dependent upon site-specific factors, would be considered prior to the decision to deploy the mobile treatment system at a location. For reasons discussed in the next section, the reactivity of the chemicals suggests that groundwater contamination would not be a significant threat.

6.5.4 Immediate Human Health Effects

The chemicals used in the treatment processes are standard reagents and solvents. As explained above, the quantities of the treatment chemicals to be used at the mobile treatment facilities would represent a very small fraction of the amounts of these substances transported daily across the country for a variety of purposes.

Exposure to concentrated solutions of the treatment chemicals could cause acute effects attributable primarily to local irritation of the tissues at the point of contact. These effects could include irritation of the eyes, skin, and mucous membranes of the respiratory tract, burning sensation in the throat, coughing, wheezing, and aggravation of pre-existing asthma and pulmonary diseases. Direct contact of the tissues with concentrated solutions of most of these substances could cause burns, particularly if no quick effort were made to wash these materials off of the body after a spill. Accidental release of these substances would not likely cause death unless large areas of the skin were damaged through prolonged contact with the concentrated solutions, or the tissues of the respiratory tract were substantially injured through prolonged inhalation of high concentrations of these materials in the air.

Except for chloroform and t-butyl alcohol, the treatment chemicals do not exhibit significant volatility. Thus, the accidental release of the non-volatile treatment chemicals into the air in quantities sufficient to yield airborne threats would be very unlikely. The exceptions, chloroform and t-butyl alcohol, would be expected to evaporate quickly from soils and other surfaces on which they are spilled, and dissipate rapidly in the air with increasing distance from the point of release.

6.6 Petroleum, Oil, and Lubricants

Various petroleum products would be used at a treatment site or during transport of CWM to an off-site treatment location for fuels and lubricants in generators, hydraulic systems, and mechanical equipment. Types of products present would include diesel fuel, gasoline, aviation fuels, hydraulic fluids, and lubricants.

Diesel fuel would be used at a treatment site as fuel for electric power generators. Emergency generators would need only about a 100-gallon tank, which would be enough to run for one or two hours to allow the safe shutdown of the treatment systems if utility power was lost. If a generator must be used at site to produce all site power, several hundred gallons could be present in fuel and storage tanks, and regular fuel deliveries would be made by truck.

Aviation fuels and lubricants would be used for aircraft transporting CWM to an off-site treatment location. Fueling and maintenance of these aircraft would most likely take place at the military installation where the aircraft are based. Diesel fuel or gasoline would be used as fuel for trucks that transport CWM items to an on-site treatment system or to and from aircraft used for transport off site. It is likely that these vehicles would be fueled and maintained at a nearby military motor pool facility or commercial service station unless these services were not conveniently available.

Equipment at a treatment site could have hydraulic systems that use petroleum-based hydraulic fluids. Lubricants of various kinds for mechanical equipment would also be present.

6.6.1 Accidental Release Mechanisms

Stored fuels could be released from storage tanks if the tanks are accidentally punctured, such as in a vehicle accident or from an accidental detonation of a munition, or if an external event such as an earthquake or tornado ruptures the tank. A truck or vehicle accident could also release onboard fuel. A broken or burst hydraulic hose could release hydraulic fluid from equipment. Lubricants could be spilled from storage containers or from equipment lubricant reservoirs.

6.6.2 Environmental Impacts

The petroleum products used in largest quantity at a treatment site would be diesel fuel for generators. The risk to the environment from a spill would be greatly reduced by site planning. The threat of spilled fuel running into aquatic systems would be reduced or eliminated by considering this threat in site planning, such as to the location of the generator and fuel storage and by constructing appropriate spill containment devices. The threat to groundwater would be a site-specific consideration during site selection and planning. This threat could be greatly reduced or eliminated by constructing spill containment devices and by implementing spill response and cleanup standing operating procedures that would be in place at all treatment sites. Spill-contaminated soil would be cleaned up quickly under the site standing operating procedures in place at a site.

Fuels and lubricants for aircraft used for transport of CWM to an off-site treatment location would likely be stored at an existing airfield where the aircraft would be based. These locations would already have in place spill containment and response systems and plans for stored fuel and spilled petroleum products required under federal, state, and DoD regulations.

Fuel and lubricants for trucks used for on-site and off-site CWM transport would most likely be stored at existing military or commercial facilities. These locations would already have in place spill containment and response systems and plans for stored fuel and spilled petroleum products required under federal, state, and DoD regulations.

Spilled hydraulic fluids would not likely be a significant threat to the environment. Only small quantities could be spilled from hydraulic systems or from storage containers, and standing operating procedures would be in place to respond quickly to spills that occurred.

Spills of lubricants at a treatment site would not likely be a significant threat to the environment. Only small spills would likely occur because only small containers of lubricants would likely be present at a site. Standing operating procedures would be in place to respond to any spills that occurred.

6.7 Accident Response and Cleanup Requirements

If hazardous materials were accidentally released to the environment, there would be an immediate response by the appropriate organizations in accordance with emergency response plans and procedures to help protect public health and safety and the environment. After the immediate response is completed, there would also be a site-specific investigation and evaluation to determine any remedial action needed to ensure the long-term protection of human health and the environment from residual contamination that might still remain in the environment. The investigation would consider a number of factors and could involve a variety of activities that would depend on the circumstances of the release and characteristics of the area of the release. Described below are the laws, regulations, and guidance that determine and direct response and cleanup activities; some factors that could be considered to evaluate the potential for long-term threats to human health and the environment; and the activities that could be carried out to determine the nature and extent of the cleanup required.

6.7.1 Cleanup Laws and Regulations

If an accidental release were to occur at a treatment site or during transportation, appropriate response would be carried out under CERCLA, RCRA, HMTA, EPCRA, and/or other applicable federal, tribal, state, and local laws and regulations, as well as military regulations (see Sections 3, 4, and 5.3.12). For example, CERCLA establishes a framework for preparing for and responding to releases of hazardous substances, pollutants, and contaminants. CERCLA, in conjunction with the National Contingency Plan (NCP), identifies and defines roles for USEPA, states, and federal agencies, such as DoD (and its components), in the planning and response processes. Three fundamental kinds of activities are performed pursuant to the NCP, as specified under 40 CFR 300: preparedness planning and coordination, notification and communication; and response operations at the scene of a discharge or release.

CERCLA and the NCP create two types of organizations to perform these activities: a National Response Team and Regional Response Teams. The National Response Team is

responsible for national response and preparedness planning, for coordinating regional planning, and for providing policy guidance and support to the Regional Response Teams. The National Response Team consists of representatives from the federal agencies specified in 40 CFR 300.175. The Regional Response Teams are responsible for regional planning activities before a response occurs and for providing advice and support to the on-scene coordinator or remedial project manager when activated during a response. The Regional Response Teams consist of representatives from each federal agency participating in the National Response Team plus state and (as agreed upon by the states) local government representatives.

RCRA provides additional requirements that would apply to releases of hazardous waste. For example, RCRA transport standards under 40 CFR 263 require hazardous waste transporters to take immediate action—including notification of proper authorities—in the case of a release during transport. The transporter must clean up any hazardous waste discharge that occurs during transportation or take such action as may be required by federal, state, or local officials so that the hazardous waste no longer presents a hazard to human health or the environment. RCRA hazardous waste TSDF standards under 40 CFR 264 contain various requirements for detecting and responding to releases. These include requirements for inspections, training, preparedness and prevention, contingency plans and emergency preparedness, monitoring and detecting releases, and responding to any such releases (see Section 4.6.1.2).

6.7.2 Immediate Response

For releases at a treatment site, the Army would implement the site-specific emergency response plan, which could also include simultaneous response by other DoD organizations and by local and state authorities, depending on the circumstances of the release (see Section 3.1.3). First responders to a release during off-property transportation of CWM items by truck or aircraft would be the accompanying military personnel and local authorities until standby military emergency response personnel could arrive at the scene as quickly as possible (see Section 3.16). Transporters and local hazardous material response units, police, and fire departments would be the first responders to spills during highway transport of neutralent wastes and treatment chemicals in accordance with local plans for responding to hazardous material release incidents.

6.7.3 Cleanup Investigations and Remediation

If an accidental release were to occur, there could be a need to investigate or remediate residual contamination at the site after the immediate response. These activities could be needed to ensure the long-term protection of human health and the environment. These activities would be determined on a site-specific basis and would partly depend on the circumstances of the release and other factors, as discussed below.

6.7.3.1 Evaluating the Potential for Long-Term/Chronic Threats

If needed, site-specific evaluations of the potential for long-term/chronic threats would be performed with the involvement of the appropriate federal, state, tribal, and local stakeholders. Long-term/chronic threats could be possible if the released material or a breakdown product remained in the environment in a harmful form for a long-enough period of time. The potential for long-term/chronic threats to the environment or public health would also depend on the likelihood of exposure to the chemical and the toxicity of the chemical at its concentrations in media to which human populations of the environment could be exposed . The media of concern for potential long-term/chronic threats would be principally air, soil, groundwater, and surface waters. Each of these media could be examined site-specifically, as appropriate, to determine the likelihood of exposure and/or the toxicity of the chemicals in the medium.

In the event of an accidental release, it could be important to know whether any of the released chemicals has the potential to remain in soil, water or air long enough to present a threat. This could be important to enable clean-up efforts to be designed appropriately to reduce or eliminate the potential for long-term/chronic threats to the environment or public health. Accordingly, any clean-up efforts that could be warranted for a site would be adequate to ensure the long-term protection of human health and the environment from any of the accidental releases that could occur. These issues are discussed further below.

Exposure Evaluations

The accidental release of hazardous materials into the environment has the potential to cause harm if the release results in exposure of the people or the environment to toxic amounts of these materials. Exposure evaluation would estimate the amount of a contaminant that the general public or the environment might contact at an exposure point after an accidental release. Exposure evaluation would consider the concentrations of the contaminants in various environmental media at the point of release and at potential exposure points, the environmental fate and transport of the contaminants to potential exposure points, the likely magnitude, frequency, and duration of contact with human or ecological populations at exposure points, and other exposure parameters.

For example, how long a hazardous material persists in the environment after an accidental release would be an important property that could substantially influence the potential for exposures after an accidental release. Persistence of a hazardous chemical in the environment would partly determine how long it could continue to pose an immediate threat and whether it could remain in the environment long enough to pose a long-term/chronic threat.

In the context of potential exposures to environmental contaminants, a chemical can be considered to be nonpersistent if it degrades within a day to a few days, moderately persistent if it degrades within a few days to weeks, and highly persistent if it remains in the environment for months to years.

For example, the chemical warfare agents and industrial chemicals are generally considered to be nonpersistent or moderately persistent substances, and would thus unlikely pose long-term/chronic threats to either human health or the environment from accidental releases (e.g., see Appendix F; Department of the Army, 1999d; Rosenblatt et al., 1975). Exceptions to this include the sulfur mustards (H, HD, HT) and lewisite (L), which could persist in the environment for many years if released in bulk quantities under certain circumstances. However, bulk quantities of sulfur mustards (H, HD, HT) or lewisite (L) are unlikely to remain in the environment if spilled in bulk form. Any accidental spills of bulk agent would be cleaned-up immediately. Any explosive release of agent would be expected to disperse the agent in the air, which would preclude deposition of bulk forms of the agent on the ground.

In contrast, some of the chemicals that would be associated with the transportable treatment systems can be highly persistent in both water and soil, and could have the potential to pose long-term/chronic threats after an accidental release. For example, a few of the primary environmental degradation components of the chemical warfare agents are typically characterized as persistent. These substances include 2 -chlorovinyl arsenous acid/lewisite oxide mixture and inorganic arsenic from lewisite (L); EA 2192 from VX; thiodyglycol from sulfur mustards (H, HD, HT); methyl phosphonic acid (MPA) from sarin (GB), soman (GD), or VX; isopropyl methylphosphonic acid (IMPA) from sarin (GB); and ethyl methylphosphonic acid (EMPA) from VX (Department of the Army, 1999d; Munro et al., In press). The rates of further breakdown of these environment degradation components to final, relatively innocuous breakdown products would depend on site-specific factors, including the concentrations of these substances in soil, water or air to which human populations or the environment could be exposed, ambient temperature, humidity of the air or moisture content of soil, and so forth.

The potential for a hazardous material to bioaccumulate in the food web is another property that could substantially influence the potential for exposures to toxic amounts of these materials for both human and ecological populations. Bioaccumulation is the net accumulation of a substance by an organism as a result of uptake from all environmental sources. Environmental contaminants can accumulate in the tissues of organisms or bioaccumulate throughout the food web at concentrations that are many times greater than in the contaminated soil or water to which the organisms are exposed. Organisms and/or human populations can be adversely affected if the accumulated concentration of a contaminant in food is great enough.

The potential to bioaccumulate has been measured experimentally for many chemicals. It can also be estimated from chemical properties using several methods. For organic chemicals, the octanol-water partition coefficient (K_{ow}) of a chemical can be used as an indicator of bioaccumulation potential. It is generally recognized that compounds with log K_{ow} values less than 3 or 4 do not bioaccumulate (Baird, 1995). The log K_{ow} values for many substances are given in Appendix F.

Toxicity Evaluations

The accidental release of hazardous materials into the environment has the potential to cause harm depending on the toxicological properties of the material in the soil, water, or air to which human populations or the environment could be exposed. The quantities of a chemical that would pose a threat in soil, water, or air would depend, among other factors, on its toxic potency in each of these media. Toxicity evaluation characterizes the relationship between the exposure concentration or dose of a hazardous substance and the possible occurrence of an adverse effect on human health or the environment.

For example, chemicals released to the environment generally degrade to produce some breakdown products that can be toxic but not persistent, and other breakdown products that can be persistent but not toxic. To use chemical warfare agents as examples, the persistent but relatively non-toxic primary environmental degradation components typically include thiodyglycol from sulfur mustards (H, HD, HT); methyl phosphonic acid (MPA) from sarin (GB), soman (GD), or VX; isopropyl methylphosphonic acid (IMPA) from sarin (GB); and ethyl methylphosphonic acid (EMPA) from VX (Department of the Army, 1999d; Munro et al., In press). These substances are unlikely to pose significant long-term/chronic threats after accidental release at a site, despite their potential persistence in the environment. In contrast, primary environmental degradation components that are believed to be significantly toxic (as well as highly persistent) include 2-chlorovinyl arsenous acid/lewisite oxide mixture and inorganic arsenic from lewisite (L), and EA 2192 from VX (Department of the Army, 1999d; Munro et al., In press). These latter substances are more likely to be released in quantities sufficient to pose long-term/chronic threats, and may therefore need to be investigated after an accidental release at a particular site.

Risk Assessments

The factors that would determine the potential for long-term/chronic threats could be evaluated in site-specific human health and ecological risk assessments. Any ecological or human health risk assessment would be performed in accordance with applicable federal, state, and local regulations, current risk assessment procedures and guidance provided by the DoD component (e.g., Army Engineering Manual 200-1-4, 1995 and 1996; Department of the Army, 1996b, 1999d; Department of the Air Force, 1994, 1997; Department of the Navy, 1997) and USEPA (e.g., U.S. Environmental Protection Agency, 1989b, 1991a&b, 1992b). The specific approach to risk assessment taken at a specific site would also be based on stakeholder involvement.

The risk assessments would include site-specific exposure evaluations and toxicity evaluations that would evaluate the potential for exposure and the toxicity of each of the chemical warfare agents, environmental degradation components, industrial chemicals or other substances that could be accidentally released. These evaluations would be based on information such as that provided in Appendix E, Appendix F, and other references (e.g., Department of the Army 1999d; Munro et al., In press), as well as site-specific factors, to

evaluate the potential for long-term threats at the site. These evaluations would also comply with all pertinent executive orders, such as Executive Order 13045.

Under Executive Order 13045 each federal agency is responsible for identifying and assessing environmental health risks and safety risks that may disproportionately affect children. In performing site-specific safety and risk assessments, the NSCMP and other agencies are required to address any disproportionate risks to children that could result from exposure to substances that children could come into contact with, such as air, food, and soil. In keeping with this requirement, site-specific safety and risk assessments would include evaluation of exposure assumptions representing exposure during childhood (Department of the Army, 1999c).

6.7.3.2 Cleanup Activities

If hazardous chemicals are accidentally released to the environment, there would be an immediate cleanup response, and there could also be a site-specific investigation, exposure evaluation, and/or toxicity evaluation to ensure the long-term protection of human health and the environment. These investigations and evaluations would be conducted as described above, including the involvement of appropriate federal, tribal, state, and local stakeholders.

If needed, cleanup goals could then be established in accordance with guidance from various sources, such as those provided by the DoD component (e.g., Department of the Army, 1999d; Munro et al., in press; Department of the Air Force, 1994, 1997; Department of the Navy, 1997) and by other agencies (e.g., U.S. Environmental Protection Agency, 1991c&d, 1996b, 1999b&c). For example, the Army has developed and recommended health-based environmental screening concentrations that could be used, as appropriate, as cleanup goals for chemical warfare agents that could be accidentally released to soil at specific sites. These screening concentrations are presented in *Derivation of Health-Based Environmental Screening Levels (HBESLs) for Chemical Warfare Agents* (Department of the Army, 1999d). The Army's health-based environmental screening levels are comparable to screening concentrations that have been developed by USEPA Region IX, USEPA Region III, and USEPA Headquarters for numerous other substances in soil, water, and air. These substances include some of the weaponized industrial chemicals, treatment wastes, and environmental degradation components. Available USEPA toxicity values (i.e. reference doses, reference concentrations, slope factors, and unit risks), which are used to calculate the environmental screening levels, are presented in Appendix E.

All of the environmental screening levels were developed to protect the general population from potential long-term/chronic exposures to residual levels of chemicals in the environment. They are developed to serve as conservative clean-up goals for use in evaluating contamination after a release and verifying adequate cleanup after a remediation effort.

However, it is important to note that state and local requirements may specify the use of other approaches for conducting site-specific evaluations and developing site-specific clean-up goals. Further, one approach may be more appropriate than another for certain situations,

depending on the nature of the release (e.g., spill, explosive release), the media contaminated (e.g., air, groundwater, surface water, sediment, soil), the properties of the released chemicals (e.g., persistence, toxicity, potential to bioaccumulate; see Appendices E and F), likely exposure pathways and routes of exposure (e.g., inhalation, ingestion, skin contact; see Appendix E), and potential for exposure to multiple contaminants simultaneously through multiple pathways. Thus, the approach used at a specific site would be a risk management decision that would depend on state, local, and USEPA requirements, as well as the involvement of stakeholders (Department of the Army, 1999d).

In general, soil sampling and other studies could be conducted to determine the amount of environmental contamination remaining from the accidental release. The results of this investigation could lead to the development of additional cleanup strategies to reduce or eliminate potential exposures to the residual contamination. The level to which cleanup would take place and the goals to be met would be decided in conjunction with federal, tribal, state, and local regulatory authorities.

6.8 Adverse Impacts That Cannot be Avoided

Releasing chemical warfare agents and some industrial chemicals into the environment could cause unavoidable adverse impacts.

Releasing chemical warfare agents or industrial chemicals could cause harm to people and other organisms in the downwind area. The number of people (if any) harmed would depend on the area covered by of the plume beyond controlled areas, the number of people in the plume area, the warning time given, and the Army response to the release. The effect on other organisms would depend on the type of environment within the plume area.

If a transportation accident spilled neutralent wastes into a water body, aquatic organisms could be affected at and near the site of the spill. Downstream drinking water systems could be temporarily affected. If arsenic is present in the waste, it could remain in the sediments unless there was a response action to remove it or reduce the amount left. Because arsenic would be present in low concentration in the waste, the increase in sediment concentration would likely be small.

Economic activity could be adversely affected in the area contaminated by a release until decontamination and clean up could restore the area to normal use. Traffic on the route where a spill of neutralent waste occurred could be disrupted until the hazardous material was cleaned up.

If a historic structure and grounds were contaminated by released material, it could be damaged by decontamination and cleanup activities.

6.9 Irreversible and Irretrievable Commitments of Resources

Responses required for an accidental release of hazardous substances would result in some irreversible and irretrievable commitment of resources. These would be time of workers and medical personnel, chemicals and materials, and landfill capacity.

The time of workers and medical personnel needed to decontaminate and clean up contaminated area and to care for people injured by the accident would be irreversibly committed.

Decontamination chemicals and materials would be irreversibly committed because most wastes would be disposed of permanently in landfills or by other permanent destruction methods as required under RCRA and other federal, state, and local statutes and regulations.

Placing solid and hazardous wastes generated from decontamination and cleanup activities in solid and hazardous waste landfills would have the practical effect of irreversibly committing this landfill space to wastes from this activity. This space would be unavailable for wastes from other sources.

6.10 Relationship Between Short-Term Uses of Man's Environment and the Maintenance and Enhancement of Long-Term Productivity

Using transportable treatment systems to process and treat non-stockpile CWM would result in a short-term risk of releasing hazardous substances into the environment at a treatment site. Operating at a site with such a short-term risk would permanently eliminate potential future risks to human health and safety and the environment from buried and stored CWM that were treated and processed at the site.

Areas affected by a release of hazardous substances would suffer a short-term effect since most of the hazardous compounds would degrade in the environment to less hazardous or harmless compounds. Decontamination and cleanup activities would shorten the time further. After the hazardous chemicals degrade or are cleaned up, the areas would return to their original uses.

Arsenic compounds would remain in the environment once released if it is not cleaned up.

If a historic structure or grounds were damaged permanently by the hazardous chemicals and/or the decontamination and/or cleanup activity, this would be a long-term impact of the short-term activities at a treatment site.

6.11 Cumulative Impacts

Various other ongoing or future planned actions could occur in the vicinity of any site used to treat CWM in a transportable treatment system, any site used to manage wastes generated from the transportable treatment system, and/or any other site at which an accidental release of hazardous substances could occur from the transport of CWM to a

treatment site or from the transport of treatment system wastes to waste management facility. The nature and impacts of these other actions would be very site-specific. The cumulative impacts resulting from accidental releases of hazardous substances from the various treatment system operations and the impacts of these other actions would also be very site-specific. These cumulative impacts would be considered in the additional site-specific environmental reviews conducted by the Army when a decision is to be made about how and where to process and treat non-stockpile CWM stored or buried at a specific site.

Section 7

Environmental Consequences of the No-Action Alternative

This section describes the possible environmental, socioeconomic, and human health effects of the no-action alternative as described in Section 3.2. If this alternative were selected, the Army would suspend or discontinue the development of transportable treatment systems and continue to conduct research and development on other treatment technologies and methods until one or more could be developed into one or more systems that could be deployed in the field to treat non-stockpile CWM. While the Army continues research and development, any non-stockpile CWM munitions or containers that are currently in long-term storage would remain in storage, and any non-stockpile CWM munitions or containers recovered from burial sites or firing and test ranges in the future would be placed into long-term storage. CWM in storage or recovered from burial sites and test and firing ranges would be treated in the future when a treatment method is developed and deployed.

Sections 7.1 through 7.4 are concerned with the impacts of normal operations and activities that would take place if the Army selects the no-action alternative. Normal operation means that all activities and operations would take place as planned and designed and within regulatory limits without any accidental releases of hazardous substances.

Section 7.5 describes the impacts that could occur if hazardous substances are accidentally released to the environment during activities and operations at a burial, recovery, storage, or treatment site or during associated transportation activities. Hazardous substances that could be released accidentally include chemical agents or industrial chemicals in CWM items, chemicals used in future treatment processes, waste products from future treatment processes, and fuel oil and other petroleum products used in operations.

There is a very low risk of releasing hazardous substances during activities that would take place under the no-action alternative. The Army has conducted an accident risk assessment to determine what accidents could occur and the likelihood of occurrence (Department of the Army, 1999b). The results of these analyses are summarized below and discussed in Appendix D. Appendix E provides data on the human toxicity characteristics of many of the hazardous chemicals. Appendix F provides data on the physical characteristics and transformation and fate in the environment of these substances.

The environmental impacts described in this section are programmatic in nature, as discussed in Section 1.3. The only Army decision to be made under the no-action alternative is whether to suspend or discontinue development of the transportable treatment systems described in Section 2 and Appendix C and to continue reviewing and assessing other treatment technologies, methods, and processes. When a deployable treatment method is

developed in the future, the Army would conduct additional environmental, safety, and other reviews at that time before finalizing the design and making the system or systems available for deployment.

7.1 Burial Sites

Environmental management activities would continue as they are currently carried out at non-stockpile CWM burial sites while the Army finds and develops another method or technology into one or more systems able to treat, process, or destroy chemical warfare agents or industrial chemicals in non-stockpile CWM munitions and containers in a safe and cost-effective manner. These continuing activities at burial sites are described in Section 1.9.

Environmental management at burial sites would be carried out under the requirements of RCRA or CERCLA and other federal, tribal, and state regulation to ensure public health and safety at each location. These activities would be independent of whether the Army implements the preferred alternative (described in Section 3.1) or the no-action alternative (described in Section 3.2). These environmental management activities would not be under the control of the NSCMP (see Section 1.8); would be subject to environmental review and analysis; and require public comment and input in the decision-making process. Therefore, the environmental impacts of these activities are not described here since they would be considered as part of the decisions made for these other programs.

7.2 Storage Sites

This section describes the potential environmental, socioeconomic, and public health and safety impacts that could occur during normal operations at long-term CWM storage sites until new CWM treatment and processing methods could be developed by the Army. CWM items currently in storage would remain in storage, and CWM items recovered in the future from burial sites or test and firing ranges would be placed in long-term storage.

CWM items recovered in the future could be stored in existing facilities or in an IHF erected for this purpose. If an existing ammunition magazine or igloo is used, some modification of the building could be needed to meet Army safety requirements for storing CWM. Storage facilities would also have to meet federal, state, and local requirements. Modifications could include sealing drains, modifying ventilation systems, installing chemical agent monitoring ports, and constructing additional security features, such as fencing and lighting. If an IHF is used, a site would be prepared and an IHF brought to the site and erected (see Section 2.5 for a description of an IHF site).

Storage of CWM items could be on the military installation or property where the CWM is recovered or it could be elsewhere. If storage is on the property where the items were recovered, a truck would transport CWM items from the burial site to the storage building. If storage is elsewhere, a truck and/or an aircraft would transport the CWM items from the burial site to the off-property storage location. Section 3.1.6 describes transport activities.

7.2.1 Air Quality

The setup and operation of a long-term storage facility would generate various air emissions at a site. The types and quantities of emissions generated would be site-specific and would depend on a variety of factors at the site. Major factors affecting emissions would include the specific site preparation and setup activities conducted at the site; the specific equipment and vehicles used; the time required for site preparation and setup; the timeframe over which CWM items would remain in storage; the physical characteristics of the site; federal, tribal, state, and local air quality regulations applicable at the site; and the air pollution controls and mitigating measures that would be implemented at the site.

Air emissions generated would include criteria pollutants released by vehicles and equipment involved in site preparation and operational activities and in the transport of personnel, equipment, materials, and wastes. Fugitive dust would be released by vehicles, equipment, and activities that disturb the ground surface. HAPs could also be released by vehicles, equipment, and various construction-related activities, such as painting and solvent cleaning, and by similar maintenance activities during storage operations.

Air quality impacts from these emissions would be very site-specific. Major factors that would affect impacts include (1) the specific types and quantities of emissions that would be released, (2) existing air quality levels in the area, including the area's attainment status, (3) applicable federal, state, and local air quality regul ations, including any state and local regulations that are in addition to, or more stringent than, the federal requirements, and (4) other local site-specific issues.

7.2.1.1 Storage Site Preparation and Setup

Long-term storage of recovered CWM would occur in either an existing building, such as an existing ammunition magazine or igloo, or in an IHF erected for such a purpose. If an existing building were to be used, some modification of the building could be required to meet federal, state, and local regulatory requirements, as well as Army safety requirements for storing CWM. If an IHF were to be used, a site would need to be prepared and the IHF brought to the site and erected (see Section 2.5).

The activities and equipment that would be needed to prepare and set up a storage site would be similar to those needed to prepare a site for a transportable treatment system. However, preparing a storage site and setting up or modifying a storage facility would tend to be less extensive, produce smaller quantities of air pollutants, and have a lesser impact on air quality than preparing a site for a transportable treatment system.

Air emissions could be emitted during storage site preparation and setup by the following types of sources: fugitive dust-generating activities, diesel-powered generators, mobile sources such as vehicles and construction equipment, and miscellaneous construction activities. The types of emissions that could be generated by each of these sources would be similar to those

discussed in Section 5.2.1.1 for the transportable treatment systems. These emissions would include criteria pollutants, fugitive dust, and HAPs.

Fugitive Dust-Generating Activities. Various site setup and preparation activities would generate particulates in the form of fugitive dust. Sources of fugitive dust would include any activities that physically disturb the ground surface at the site, such as any necessary grading, clearing of vegetation, and excavations for any footings required at a specific site. Cleared areas could also become a source of wind-blown dust, as could any debris and spoil piles produced by construction activities. Fugitive dust could also be generated in loading debris and spoils into vehicles for transport to disposal locations. Personal vehicles, trucks, and heavy equipment would also generate fugitive dust when traveling over paved and unpaved roads. Fugitive dust could also be generated if site setup included any modifications to existing storage facilities at the site.

The amount of fugitive dust emissions generated would be very site-specific and would depend upon such factors as the amount of land disturbed, the specific activities conducted at the site and the timeframe over which they are conducted, the number and types of vehicles and other mobile equipment used at the site, the vehicle-miles traveled on paved and unpaved roads, the dust suppression and other mitigating measures used at the site, and such local factors as wind speed and the silt and moisture content of site soils.

State and local regulations and military installation requirements could dictate controls, such as covering trucks hauling dirt, sand, soil, or other loose material; applying water or other dust suppressants; or restricting activities on days with unfavorable meteorological conditions. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process, as discussed below.

Diesel-Powered Generators. Diesel-powered generators could be used to generate electrical power during site setup and preparation at various sites, either as the primary source of power or as an emergency backup. When used, diesel-powered generators would emit such criteria pollutants as nitrogen oxides, sulfur oxides, carbon monoxide, hydrocarbons, and particulate matter. Diesel-powered generators would also emit small quantities of some HAPs such as acetaldehyde, acrolein, benzene, 1,3 -butadiene, formaldehyde, naphthalene, propylene, toluene, and xylenes (U.S. Environmental Protection Agency, 1996a). Emission quantities would be site-specific and would depend upon such factors as the hours of operation and the amount of power generated. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process, as discussed below.

Mobile Sources. Mobile sources of emissions would include trucks, personal vehicles, and heavy construction equipment used at the site. Trucks would be used to transport the construction equipment and supplies, and possibly the interim storage facility itself, to the

site and to transport construction-related wastes from the site. Personal vehicles would be used to transport workers to and from the site. The construction equipment used would depend on the specific construction activities carried out and could include graders, bulldozers, forklifts, and similar equipment.

The mobile sources would release criteria pollutants. Emission quantities would be site-specific and would depend upon such factors as the vehicle-miles traveled by the cars and trucks and the total number of hours that heavy-duty construction equipment is operated.

Miscellaneous Sources. Various other construction-related activities, such as painting, solvent cleaning, and equipment maintenance, would produce small amounts of solvent-based emissions that could include both HAPs and other volatile organic compounds. These emissions would be extremely site-specific and would depend on the activities conducted, the materials used, and the timeframe over which they are used. Any necessary mitigating measures and controls needed at a specific site would be determined as part of the site-specific air quality review and approval process as discussed below.

Air Quality Impacts. Air quality impacts from storage site preparation and setup would be extremely site-specific. As discussed in Section 5.2.1.2, air quality impacts would depend upon such factors as the specific types and quantities of air pollutants emitted, existing air quality in the area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts would have to be in compliance with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented during site preparation and treatment system setup as necessary.

All necessary air quality reviews, permits, and approvals would need to be obtained as discussed in Sections 5.2.1.2 and 5.3.1.2. The need for additional controls and mitigating measures would be identified and implemented based on these reviews, permits, and approvals.

7.2.1.2 Storage Facility Operation

Once the storage facility became operational, air emissions would be generated primarily by activities related to facility maintenance and security, to monitoring and inspection of stored CWM items, and to the any necessary offsite transport of wastes generated by the storage operations (see Section 7.2.6.2).

These emissions would be generated by vehicles used to transport workers to and from the storage facility, to transport supplies to the facility, and to transport wastes from the facility. The vehicles would emit criteria pollutants and generate fugitive dust as discussed above. Maintenance operations, such as painting and solvent cleaning, would produce small amounts of solvent-based emissions that could include both HAPs and other volatile organic compounds.

In addition, diesel-powered generators could be used at some storage sites to produce the electrical power needed to operate storage facility lighting, monitoring systems, and security systems, either as the primary source of power or as an emergency backup (see Section 7.2.7). If used, these generators would release criteria pollutants and HAPs as discussed above.

Air quality impacts from storage site operations would be extremely site-specific. The air quality impacts would depend upon such factors as the specific types and quantities of air pollutants emitted, existing air quality in the area (including the area's attainment status), and existing emission levels in the area. All emissions and any air quality impacts would have to be in compliance with applicable federal, state, tribal, and local laws and regulations. Appropriate site-specific controls and mitigating measures would be implemented as necessary.

All necessary air quality reviews, permits, and approvals would be obtained as discussed in Sections 5.2.1.2 and 5.3.1.2. The need for additional controls and mitigating measures would be identified and implemented based on these reviews, permits, and approvals.

7.2.2 Noise

Potential noise sources could include earth-moving and other construction equipment during the site preparation and setup phase and by transport trucks during the transfer and storage phase. Noise levels and types would be comparable to those generated by a small construction site. Noise impacts would occur during normal work hours and would be of limited duration. Also, because the storage sites would usually be located away from inhabited areas for safety reasons, any noise generated at the site would be attenuated by distance.

There would be insignificant impacts during the period that the non-stockpile CWM items were stored in the IHF or existing storage facilities from occasional vehicle traffic to monitor and maintain stored items.

7.2.3 Geology, Minerals, and Soils

Soils could be affected by ground-disturbing activities necessary to prepare storage facilities for recovered CWM. Modifying existing buildings or bunkers to store CWM would likely have little or no effect on soils. Constructing a site for a new storage building, such as an IHF (see Section 2.5), could affect soil at the construction site from grading, building access roads, constructing foundations, trenching to install utilities, and erecting security fencing. The extent of impacts on soils would be determined by the characteristics of each specific site and the mitigating measures implemented at each site. These impacts would continue as long as the building remained at the location.

If a new storage building is needed, prime and unique farmlands and farmlands of statewide importance would be identified during the site selection process and impacts determined, as required under the Federal Agricultural Improvement and Reform Act and the Farmland Protection Act. These lands would be avoided or mitigating measures would be

implemented to reduce or eliminate impacts to these resources. Mitigating measures could include removing and stockpiling topsoil and implementing special soil erosion procedures and methods.

Access to economically important subsurface minerals underlying or near the storage site could be restricted or eliminated while the site is used for storing CWM.

7.2.4 Groundwater

It is unlikely that activities at the storage site would have much potential to affect groundwater resources. It is unlikely that wells would be drilled at the site. Ground-disturbing activities would be shallow construction activities. Site grading, if needed, could possibly change groundwater recharge characteristics somewhat at the site. The extent of impacts, if any, would be determined by the characteristics of the specific site.

If a new storage site is needed, the presence of sole-source aquifers, wellhead protection areas, and source-water areas would be determined during the site-selection phase in coordination with state and local jurisdictions. Impacts to these resources, as required under the Safe Drinking Water Act, would be determined and mitigating measures implemented if required. Mitigating measures could include special spill-response procedures or putting in place special measures to contain or control spills.

7.2.5 Ecological Environment

Effects on the ecological environment would depend on the circumstances of each specific site and the ability to select the location of the storage site so as to reduce or eliminate adverse impacts. Potential ecological impacts would be considered as part of the site-selection process. Impacts identified would be a factor in selecting the site location and in determining mitigating measures required.

7.2.5.1 Upland Environment

Use of an existing building would be likely to have only minor effects on the upland environment. If a new building must be erected, the upland environment could be affected by clearing vegetation, grading, placing gravel, constructing access, constructing footings and foundations, and placing the structure. The extent of these impacts would depend on the existing physical status and prior disturbance of the site selected.

7.2.5.2 Wetland and Floodplain Environments

It is unlikely that wetlands or floodplains would be significantly affected by storage activities because it is highly unlikely that new storage facilities would be located in these environments. If an existing storage building is used that is located in former wetlands, it is unlikely that additional impacts would result from modifying the building for storing CWM.

The U.S. Army Corps of Engineers with the concurrence of the USEPA administer regulations on activities in wetlands and issue permits for these activities under the

provisions of Section 404 of the Clean Water Act. In the unlikely situation that a storage facility must be build on a wetland and a permit is issued for the activity, the permit would contain measures to mitigate the impacts. Mitigating measures could include constructing wetlands at another location to offset the loss of wetlands at the storage site or restoring the effected wetlands when the site is closed after storage is no longer needed.

Sediment runoff from constructing a new storage site could also affect adjacent wetlands. Adverse effects would likely be controlled to an acceptable level or eliminated by sediment control management measures that would be required at the construction site by many states and by all military installations. State and/or installation authorities must approve a site sediment control plan before site activities begin. Sediment control management measures must be installed before site preparation activities commence. Sediment control measures must be inspected and kept in proper operating condition during the entire site preparation phase.

If a storage site must be in a floodplain, the Army would comply with Executive Order 11988, Floodplain Management. This Order requires that the Army consider the impacts of the activities in a floodplain and implement measures to minimize these impacts. These considerations would be carried out as part of the site selection phase and would be implemented as part of site design and site preparation.

7.2.5.3 Aquatic Environment

Storm water runoff from the storage site into adjacent aquatic environments could contain some additional sediment and contaminants from normal leaks of fuel, oil, and lubricants. If a new site must be constructed, runoff could contain sediment because of soil disturbances during site preparation, such as grading.

Sediment and contaminants in storm water runoff from a storage site could affect aquatic environments adjacent to the site during site-preparation activities. The increase in sediment in runoff would be site-specific but is likely to be small at any site. Adverse effects are likely to be controlled to an acceptable level or eliminated by site sediment control management measures that would be required by many states and by all military installations. State and/or installation authorities must approve a site sediment control plan before site preparation activities begin. Sediment control management measures must be installed before site preparation activities commence. Sediment control measures must be inspected and kept in proper operating condition during the entire site preparation phase. Sediment in runoff would be less once the area is revegetated after construction activities are completed.

Storm water runoff could contain small quantities of hydrocarbon contaminants from normal leaks of fuel, oil, or lubricants from equipment at the site. The amount is likely to be small, however, because the volume that could be leaked or spilled would be small and standing operating procedures would be in place to contain any spill and remove any contaminated soil from the site.

It is possible that a National Pollutant Discharge Elimination System permit issued under the provisions of the Clean Water Act also could be required if storm water runoff from a site drains into a collecting system that discharges to surface waters. If a permit already exists for discharges from the storage area, the permit conditions could need to be reviewed to determine if the permit must be modified. This review would take place before site preparation activities would begin.

7.2.5.4 Threatened and Endangered Species

Any possible effects on threatened and endangered species would be a site-specific consideration and would have to be evaluated and analyzed when a specific site is considered as a storage location. Consideration of this issue would be part of the site-selection process.

The installation command or U.S. Army Corps of Engineers would determine the actual or potential occurrence of federally and/or state-listed threatened or endangered species at or near any site under consideration for storage. This determination would be made in consultation with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service and with appropriate state agencies.

The presence of a threatened or endangered species at a site or the potential to have an effect on a species when operating at a site would be a factor in the site selection process. If the site must be used or impacts cannot be avoided, the appropriate DoD authority would work with federal and/or state authorities to implement appropriate mitigating measures for that particular species and site. Mitigating measures could include habitat protection or improvement at another location or restrictions on operations at the site.

Any effects on threatened and endangered species that are due only to activities during site preparation and not other phases would be short term. Effects that are due to the presence of the storage facility at that location would last as long as the facility is present.

7.2.6 Waste Management

The long-term storage of the recovered CWM would be managed under the requirements of RCRA at some sites, under the requirements of CERCLA at other sites, and in some cases under a combination of the two programs (see Section 1.7). Since the military services intend to manage all CWM considered in this environmental impact statement as a hazardous waste (see Section 1), if the recovered CWM were stored under RCRA, storage would be subject to all RCRA requirements applicable to hazardous waste TSDFs, including RCRA permit requirements. If the recovered CWM were stored under CERCLA, the requirements —that is, the *applicable* or *relevant and appropriate requirements* (ARARs)—that would apply would be specified in the remedy selection process for the site (see Section 1.7). The principal ARAR that would be applied would be the substantive requirements of RCRA; however, a RCRA permit would not be needed.

Discussed below are the waste management requirements that would apply to the long-term storage of the CWM. Storage of the CWM would generate additional wastes, some of which could be hazardous waste and some of which would not be hazardous waste. The waste management requirements applicable to managing these hazardous and non-hazardous wastes are also discussed in this section.

The specific facilities used for long-term storage of the recovered CWM or for managing wastes generated from its storage would be determined on a site-specific basis. The military command or U.S. Army Corps of Engineers, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where the CWM would be stored and where each waste generated from storage would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

7.2.6.1 Long-Term Storage of the Chemical Warfare Materiel

A facility used for long-term storage of recovered CWM would be considered a hazardous waste TSDF and would have to comply with RCRA requirements for hazardous waste TSDFs (or with CERCLA ARARs based on these RCRA requirements). If managed under RCRA, the storage facility would have to obtain a RCRA permit before the recovered CWM could be stored there (see Section 4.6). A separate permit would be required at each site at which the recovered CWM was stored under RCRA. If managed under CERCLA, the remedy, including the ARARs, would be selected and carried out as discussed in Section 1.7.2.

In either case, the long-term storage would also have to comply with the two types of standards applicable to hazardous waste TSDFs: (1) general standards applicable to all hazardous waste facilities and (2) facility-specific standards applicable to storage units (e.g., containers and containment buildings). General standards contain requirements for siting of hazardous waste facilities as well as for security, inspections, waste analysis, training, preparedness and prevention, contingency plans and emergency preparedness, and facility closure and post-closure activities.

The facility-specific standards that could apply to the storage facility would include container standards (40 CFR 264 Subpart I); air emission standards for tanks, surface impoundments, and containers (40 CFR 264 Subpart CC); containment building standards (40 CFR 264 Subpart DD); and/or standards for hazardous waste munitions and explosives storage (40 CFR 264 Subpart EE). These standards include requirements for the location, design, and operation of the storage area, storage structure (such as an interim holding facility or igloo), and/or container, as well as requirements for inspections, containment and detection of releases, response to releases, control of air emissions from containers, and closure of the storage unit.

7.2.6.2 Management of Wastes Generated by Long-Term Storage

The setup, operation, and closure of a long-term storage facility would generate a variety of wastes at a particular site. Some of these wastes could be a RCRA hazardous waste and some would be a nonhazardous waste. The wastes would be managed (treated, stored, and/or

disposed of) in accordance with all applicable laws and regulations, as discussed below. Data are not available to estimate the quantity of wastes that could be generated annually.

The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated. The military command or U.S. Army Corps of Engineers, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

Wastes from Storage Site Preparation and Setup. Long-term storage of recovered CWM would occur in either an existing building, such as an existing ammunition magazine or igloo, or in an IHF erected for this purpose. If an existing building were to be used, some modification of the building could be required to meet federal, state, and local regulatory requirements, as well as Army safety requirements for storing CWM. Modifications could include providing secondary containment, sealing drains, modifying ventilation systems, installing chemical agent monitoring ports, and constructing additional security features, such as fencing and lighting. If an IHF were to be used, a site would need to be prepared and the IHF brought to the site and erected (see Section 2.5).

The waste streams that would result from these activities would be similar to those discussed in Section 3.1.10.1 for transportable treatment system site preparation and setup. The waste streams could consist of construction waste and debris, trash and similar solid waste, sanitary waste, and spent oils and lubricants. The volume and specific composition of each waste stream would depend upon such factors as the size of the area required for setup and operation of the storage facility; the number of personnel present and the timeframe over which they are present for storage site preparation and setup; and site-specific conditions such as whether a storage facility already exists or needs to be installed, whether an existing storage facility needs to be modified, and whether grading of the site and clearing of vegetation is necessary.

As noted, the waste streams from storage site preparation and setup would be similar to many of the waste streams generated during transportable treatment system site preparation and setup. As a result, the environmental consequences from managing these wastes would be of a similar nature to those from managing the equivalent wastes generated during transportable treatment system site preparation and setup. These environmental consequences are discussed in Section 5.2.6. Site-specific impacts would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

Wastes from Storage Facility Operation. Storage facility operations would generate a variety of waste streams at each site. These waste streams could include: spill cleanup materials, spent decontamination solutions and rinse waters, used personal protective equipment, laboratory wastes, trash, sanitary waste, and spent oil and lubricants (from

transport of recovered CWM to the storage facility). The specific composition of some waste streams (e.g., spill cleanup materials, spent decontamination solutions) would be dependent upon the specific CWM being stored at the site.

All waste streams directly associated with agent would be decontaminated and sent to a permitted, commercial hazardous waste TSDF for management. Such waste streams would include some of the cleanup materials, used personal protective equipment, laboratory wastes, and spent decontamination solutions and rinse waters. All these waste streams would be sampled and analyzed in accordance with RCRA requirements.

The remaining waste streams would be tested for the presence of chemical agent, if appropriate to the waste stream. Any waste stream identified as having agent present would be decontaminated, analyzed in accordance with RCRA requirements, and then sent to a permitted, commercial hazardous waste TSDF for management. The rest of the waste streams would each be sampled and analyzed in accordance with RCRA requirements to determine if it is a RCRA hazardous waste or a solid (nonhazardous) waste. If it were a hazardous waste, it would be sent to a permitted, commercial hazardous waste TSDF. If not, it would be sent to a permitted solid waste management facility or a wastewater treatment facility, as appropriate to the waste stream. Some sanitary waste and some liquid waste could be discharged directly to a sanitary sewer system rather than being containerized and transported to a wastewater treatment facility. Spent oil and lubricants would most likely be generated when transport vehicles were maintained at their normal maintenance locations and would be managed in accordance with the standard procedures at those locations.

The specific facilities used to manage each waste stream would be determined on a site-specific basis and would depend upon the site-specific nature and composition of the waste stream. The military command or U.S. Army Corps of Engineers, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process. The wastes would be managed in accordance with all federal, state, and local laws and regulations applicable at the treatment site and at the waste management facility. Compliance with these laws and regulations would be addressed in the site-specific analyses and documentation prepared for each site. Section 4.6 discusses the federal waste management regulations that would apply in managing the wastes at each type of facility.

The waste streams generated during storage facility operation would be more similar to some of the waste streams generated during the closure of the transportable treatment systems than to waste streams generated during the operation of the transportable treatment systems. No neutralents, repackaged industrial chemicals, bead blast residue, decontaminated munition casings, or other treatment process wastes would be generated. As a result, the environmental consequences from managing the wastes would be of a similar nature to those from managing the equivalent wastes generated during the closure of the transportable

treatment systems; however, the volume of wastes generated would likely be larger since the storage would occur over a longer period of time. These environmental consequences are discussed in Section 5.4.6. Site-specific impacts would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

Wastes from Storage Facility Closure. If a facility were constructed solely for the purpose of long-term storage of the CWM, it would be closed once all CWM being stored there was removed for treatment. If an existing facility were used for storage, the facility could either remain in operation after the CWM was removed or be closed once all CWM there was removed.

Storage facility closure, along with site closure, would generate a variety of waste streams at each site. These waste streams could include: spent decontamination solutions and rinse waters; other decontamination and cleanup materials; used personal protective equipment; laboratory wastes; debris; trash and similar wastes; sanitary waste; and spent oil and lubricants. The specific composition of some waste streams (e.g., spent decontamination solutions, spill cleanup materials) would be dependent upon the specific CWM stored at the site.

All waste streams directly associated with agent would be decontaminated and sent to a permitted, commercial hazardous waste TSDF for management. Such waste streams would include some of the cleanup materials, used personal protective equipment, laboratory wastes, and spent decontamination solutions and rinse waters. All these waste streams would be sampled and analyzed in accordance with RCRA requirements.

The remaining waste streams would be tested for the presence of chemical agent. Any waste stream identified as having agent present would be decontaminated, analyzed in accordance with RCRA requirements, and then sent to a permitted, commercial hazardous waste TSDF for management. The rest of the waste streams would each be sampled and analyzed in accordance with RCRA requirements to determine if it is a RCRA hazardous waste or a solid (nonhazardous) waste. If it were a hazardous waste, it would be sent to a permitted, commercial hazardous waste TSDF. If not, it would be sent to a permitted solid waste management facility or a wastewater treatment facility, as appropriate to the waste stream. However, spent oils and lubricants would be sent to appropriate recycling facilities. Some sanitary waste and some liquid waste could be discharged directly to a sanitary sewer system rather than being containerized and transported to a wastewater treatment facility.

The specific facilities used to manage each waste stream would be determined on a site-specific basis and would depend upon the site-specific nature and composition of the waste stream. The military command or U.S. Army Corps of Engineers, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process. The wastes would be managed in accordance with all federal, state, and local laws and regulations applicable at the treatment site and at the waste management facility. Compliance with these laws and regulations would be

addressed in the site-specific analyses and documentation prepared for each site. Section 4.6 discusses the federal waste management regulations that would apply in managing the wastes at each type of facility.

The waste streams generated during storage facility closure and site closure, if applicable, would be similar to many of the waste streams generated during the closure of the transportable treatment systems. As a result, the environmental consequences from managing the closure wastes would be of a similar nature to those from managing the equivalent wastes generated during the closure of the transportable treatment systems. These environmental consequences are discussed in Section 5.4.6. Site-specific impacts would be addressed in the site-specific environmental analyses and documentation that would be prepared for each site.

7.2.7 Utilities

Utility requirements would be relatively minor. Utilities needed for the long-term storage of non-stockpile CWM include electricity, water supply and sanitary wastewater disposal. Some electrical power would be needed to operate storage facility (igloo or IHF) lighting, monitoring systems, and security systems. Water supply and sanitary waste disposal would be needed in the short term for the personnel needed to prepare the site and storage facilities and in the long term for the few personnel needed to provide security and monitoring at the site.

The affected environment would be the existing infrastructure at a storage site. At most sites, it is likely that some or all of the necessary utilities would be available although sufficient capacity might be lacking. Remote sites or sites on remote portions of existing installation could lack all utilities. Portable systems could be needed.

7.2.8 Traffic and Transportation

Potential traffic and transportation impacts would result primarily from the site preparation and setup activities and from transfer of non-stockpile CWM from the discovery site to the storage site. Impacts of transporting non-stockpile CWM from a discovery site to an off-property storage location are discussed in Section 7.4.

Where existing storage facilities were available, trucks would bring equipment for upgrading existing storage facilities. Where an IHF would need to be deployed, a new storage site would need to be cleared, graded, and prepared for delivery and setup of one or more IHFs. This could require transport of a few items of construction equipment, such as bulldozers, loaders, and/or backhoes, to the site. Materials for construction of the pad, would need to be delivered to the site. Also, materials and some heavy construction equipment might need to be brought in to construct or upgrade access roads or construct landing areas for helicopters. Once the storage site was prepared, trucks would transport one or more IHFs to the site for setup. Workers would commute to the site daily in private vehicles. The number vehicle trips generated by this work would vary on a site-specific basis depending on the amount of work needed at each site, but it is expected that the increase in local traffic

would be of short duration (i.e., a few weeks to a few months) and not have significant adverse impacts on local traffic. In addition to roadways, air and sea modes of transport could be used to transport the IHF to a site.

Construction of any new access roads or modifications to an existing access road would be coordinated with state and local transportation officials (where necessary) and responsible site authorities to minimize potential adverse impacts to existing traffic patterns and to ensure traffic safety associated with vehicles entering onto or exiting from the access road.

Transporting the non-stockpile CWM could have potential adverse impacts on existing roads and highways if it were necessary to use them to get from the discovery site to the storage site. Impacts could include increases in traffic and restrictions or road closures during the transport of non-stockpile CWM. It is not likely that the increase in traffic would cause major changes in local traffic patterns. Temporary closure of roads during transport of non -stockpile CWM could be scheduled to minimize potential disruptions to local traffic patterns.

All transportation activities would be conducted in compliance with USDOT, tribal, state, and military transportation requirements. Prior to the transport of any non-stockpile CWM to an off-property location, a route-specific transportation plan would be developed by the NSCMP for all aspects of the transport. This plan would require the approval of the Army and would be submitted to the U.S. Department of Health and Human Services for review and recommendations. Transportation-related activities that would be addressed in these plans would include packaging, monitoring, mode of transport, routes, emergency response, and a site-specific and route-specific hazard analysis. In addition, prior to the transport of non-stockpile CWM, the Army would provide Congressional and state notification of the transport as required. Non-stockpile CWM and all hazardous waste and materials would be transported in containers meeting USDOT specifications. All hazardous waste and materials would be transported in accordance with transportation routing criteria and regulations pursuant to the HMTA.

7.2.9 Cultural Resources

At sites where no existing storage facilities are available, site preparation would require trees and vegetation to be cleared in order to establish a clear zone for the deployment of an IHF. The potential for adverse impacts to historic and culturally significant resources and lands of importance to Native Americans could result from (1) long-term conversion of land use, (2) disturbance of land, (3) noise generated during site preparation activities, and (4) the potential for accidental releases of non-stockpile CWM.

Prior to undertaking site preparation activities, site-specific consultations, research, and field surveys would be performed in accordance with Army Regulation AR 200-4 to identify whether the siting of the IHF would affect cultural, historical, archeological, or Native American sites or resources. Consultations with appropriate federal agencies and State and Tribal Historic Preservation Offices would be conducted. Additionally, Native American groups and

representatives would be contacted to determine potential Native American concerns with the direct use of land, and land that could be indirectly impacted by non-stockpile CWM activities.

Site-specific decisions regarding siting of an IHF would take into consideration the presence of historic and culturally significant resources and lands of importance to Native Americans and would attempt to avoid them or minimized adverse impacts to the extent possible.

7.2.10 Land Use

One or two acres of land would be required for the siting of an IHF. In most cases, deployment of an IHF or use of existing storage magazines or igloos at large, active military installations would not conflict with existing land uses on the installations. At small military installations, properties not under government control, and, possibly, at inactive military installations, deployment of an IHF and long-term storage of non-stockpile CWM could conflict with existing or surrounding land uses (such as residential, park, and agricultural land uses). Storage of non-stockpile CWM would preclude other uses of the land until such time as the CWM items were processed or moved to an off-site treatment location. In addition, depending on the need for and size of controlled areas established as a result of evaluating potential accidents, the potential exists that arrangements would have to be made to use private or non-military property or to restrict uses and activities on adjacent private or non-military property.

Prior to the use of any site, consultations would be made with installation commanders and other appropriate federal, tribal, state, and local agencies to determine potential land use conflicts and appropriate measures to avoid or reduce potential land use conflicts.

7.2.11 Socioeconomic Characteristics

Socioeconomic impacts include the demographic, economic, and social characteristics of the communities located on or near locations where non-stockpile CWM would be stored awaiting future treatment. Potential socioeconomic impacts could result from needs placed on existing community infrastructures and services by in-migrating workers and by disruptions and evacuations that could be caused by non-stockpile CWM handling and storage. The community impacts due to in-migrating personnel would be very small. Local contractors and labor would probably conduct site preparation and IHF setup. The greatest in-migration of personnel would occur to accomplish the recovery and transfer of non-stockpile CWM from the discovery site to the IHF or existing storage facilities. Non-stockpile CWM handling and transfer personnel could consist of contractor and military technical escort personnel that would be assigned to the location without their families for the duration of the project. They would live in motels or local apartments rented by the contractor. If local housing were not available, the contractor would provide temporary mobile living quarters. At this time it is not known how many personnel would be needed, but it would probably be less than 20. Because the recovery and transfer operations would be

of limited duration, it is likely that the presence of these personnel would have a small and short-lived impact on the surrounding community.

As discussed in Section 3.1, a controlled area for evacuation in the event of an accident would be calculated based on the risk and effects of a possible accidental release of CWM during transfer operations or storage. Evacuations of populations from their residences and from their places of work would have the potential for significant adverse socioeconomic impacts. Under the on-property storage scenario, this potential for evacuation would last as long as the non-stockpile CWM remained in storage. If the on-property storage of non-stockpile CWM were precluded by human health and safety requirements at sites, the potential for evacuations would last only until non-stockpile CWM was transported off-property. Storage of non-stockpile CWM would preclude other economic uses of the land until such time as the CWM items were processed or moved to an off-property treatment location.

7.2.12 Public Health and Safety

This section addresses public health and safety consequences that could result from activities associated with the long-term storage of recovered CWM under normal operations. These activities could include site preparation, storage facility setup or modification, storage facility operation, and storage facility closure. Under normal operations, all these activities would take place as planned and designed without any accidental releases of hazardous substances. These activities would generate various wastes as discussed in Section 7.2.6. Under normal operations, management of these wastes at waste management facilities —such as hazardous waste TSDFs, solid waste management facilities, wastewater treatment facilities, and recycling facilities—would take place without any accidental releases of hazardous substances. Any non-accidental releases from waste management activities, such as discharges of treated wastewater following wastewater treatment, would be in accordance with permit limits.

Emergency response plans, including a transportation emergency response plan, would be prepared and implemented before any items containing chemical agent or industrial chemicals were transported to the storage facility or stored in the facility. Such emergency response plans are discussed in Sections 3 and 4.

7.2.12.1 Fugitive Dust

Activities that disturb the ground surface—such as site preparation, storage facility setup, and storage facility closure—would generate fugitive dust emissions that could drift offsite. Appropriate dust suppression measures would be carried out in accordance with all applicable federal, tribal, state, local, and military regulations to minimize the potential public health consequences from the release of fugitive dust. At some sites, the ground surface could be contaminated as the result of past activities at the site. In such cases, additional mitigating measures might be necessary. The need for mitigating measures would be addressed in site-specific environmental analyses and documentation that would be prepared for each site.

7.2.12.2 Traffic Accidents

Various activities—such as site preparation, storage facility setup, transport of recovered CWM to the site, transport of wastes from the site, and storage facility closure —would generate additional truck and automobile traffic on roads in the vicinity of the storage site. This could possibly result in a small increase in the number of traffic accidents on such roads. Under normal operations, these accidents would not release hazardous substances such as chemical agents, industrial chemicals, or wastes. Any potential increase in traffic accidents would be site-specific and would be addressed in site-specific environmental analyses and documentation that would be prepared for each site.

7.2.12.3 Waste Management

Under normal operations, any non-accidental releases from waste management activities would be in accordance with permit limits. Such releases would not be expected to result in any adverse public health and safety consequences. The specific facilities used for managing each waste would be determined on a site-specific basis and would depend upon the site-specific nature and composition of each waste generated by the various activities. The military command or U.S. Army Corps of Engineers, in conjunction with appropriate regulatory authorities, would make site-specific decisions about where each waste would be managed. All necessary site-specific environmental analyses and documentation would be prepared as part of this decision process.

7.2.12.4 Health and Safety Effects on Children

Based on the environmental consequences discussed throughout Section 7.2, children would be unlikely to be exposed to disproportionate health or safety risks from site preparation and treatment system setup under normal operations (Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks). This would be verified in the site-specific environmental analyses and documentation that would be prepared for each site.

7.2.13 Environmental Justice

The potential for disproportionate environmental impacts to minority or low-income communities would depend on the location of the storage sites and the presence and proximity of minority or low-income communities to these sites. The potential impacts to nearby communities could include (1) lost economic opportunity, if new developments choose not to locate in areas in which non-stockpile CWM is stored, (2) lower property values, (3) potential evacuation impacts, and (4) an increase in potential for human health and safety impacts.

In general, selection of storage sites would be conducted based on health and safety considerations with the goal of minimizing risks and adverse impacts to any nearby populations. As part of the site identification process, site-specific public involvement programs and analyses commensurate with Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,"

would be conducted to identify concentrations of minority and low-income populations and to determine whether non-stockpile CWM activity impacts could disproportionately affect minority and low-income populations. Site-specific public outreach efforts would be conducted to both inform and solicit input from minority and low-income populations on site-specific activities. The site-specific analyses to determine potential disproportionate impacts would follow the guidance contained in DoD's Strategy on Environmental Justice (Department of Defense, 1995).

7.3 Future Treatment of Non-Stockpile Chemical Warfare Materiel

Even if the no-action alternative is selected, the Army must still develop methods and techniques to process, treat, or destroy non-stockpile CWM munitions and containers currently in storage and any that may be recovered from burial sites and firing and test ranges in the future. These methods and techniques would still be needed for several reasons, as discussed below.

The Army must still protect human health and safety and the environment at CWM burial and storage sites under the requirements of RCRA, CERCLA, and other federal, state, and DoD statutes and regulations. As described above and in Sections 1.8 and 1.9, environmental management activities would continue at burial and storage sites while the NSCMP continues research and development on other treatment methods and technologies. These environmental management activities may require treatment and destruction of CWM items recovered from burial sites as the only way to protect public health and safety and the environment at a site.

Even if the Army selects the no-action alternative, the United States must still comply with the provisions of the Chemical Weapons Convention. The Convention requires that non-stockpile CWM items that have been declared under the Convention must be destroyed in accordance with the timetables specified in the Convention (see Section 1 and Appendix H). Treatment systems must be available in time to meet the deadlines in the Convention or the United States could have to request extensions of the deadlines.

There are number of known technologies, processes, and methods that the Army could pursue; these are summarized below and treated in more detail in Appendix G. It is also possible that new destruction technologies could be developed in the future.

Since the technologies available to the Army are still in early stages of research and development, it is not possible at this time to determine their potential environmental impacts at treatment sites. However, it is likely that any technologies and methods developed and deployed to sites to destroy non-stockpile CWM would have some environmental and socioeconomic impacts. Before deploying any treatment system developed in the future, the Army would conduct the appropriate environmental review as required by the National Environmental Policy Act, Council on Environmental Quality regulations, Executive Orders, and AR 200-2.

A brief description is given below of the constraints that any treatment system designed to treat CWM must face, the components of such a system, and a synopsis of the current

status of technologies that are under development commercially that might be applicable to the treatment of CWM.

7.3.1 Treatment System Design Requirements

Commercial methods of waste disposal have long focused on direct, fuel-fired combustion. However, other technologies are being evaluated worldwide. These technologies range from the purely conceptual to fielded systems in use for specific waste streams. Some of these technologies may be applicable to the destruction of non-stockpile CWM.

The existence of a potentially applicable treatment technology is just one step in developing a system that meets the requirements for the destruction of CWM. Equally important considerations include protecting human health and the environment and conforming to engineering requirements for a deployable system. There are unique challenges associated with the destruction of CWM. The system must be capable and versatile enough to process all expected CWM items in a variety of conditions that could be encountered at CWM burial and storage sites. CWM consist of items with various quantities and kinds of chemical fills existing in varying concentrations and in different solutions. Chemicals may be liquid, solid, or gaseous. CWM includes whole and partial items as well as loose component hardware. The CWM may be pristine or highly decomposed (see Appendix B). Internal and external dimensions may vary drastically for munitions of the same design. Excessive decomposition can weaken the structural integrity of the munition making the structure fragile and vulnerable to shock and vibration during treatment operations.

The system must be compatible with the operational safety requirements associated with processing CWM. The greatest operational challenge is adapting a technology to work under the vapor and explosion containment protocols necessary for safe destruction of CWM. Pre-treatment accessing and treatment require vapor containment structures to prevent release of agent vapor. In addition, certain operations require explosion containment. Vapor containment requires sealed structures with a method of treating agent vapor release. Explosion containment is much more difficult, but is not required for CWM that are not explosively configured. Explosion containment requires a hardened structure that can withstand the destructive force of a detonation. This includes shock, overpressure, and heat as well as fragmentation (shrapnel).

Any chemical agent process must be compatible with the chemical agent monitoring equipment. Any treatment technology must be capable of verifying agent destruction and, where applicable, verifying explosives deactivation using validated sampling and analysis test methods. The type and quantity of every compound in each effluent streams must be (or eventually be) characterized.

An integrated treatment system capable of meeting these requirements will generally consist of the following four components, which are discussed in more detail in Appendix G:

- **Pre-treatment**—Operations that prepare and reconfigure feeds and materials for the treatment technologies. Pre-treatment technologies usually include gaining access to the internal chemical fills as well as preparing feed for treatment by such methods as material segregation, size reduction and chemical or thermal pre-treatment.
- **Treatment**—Operations that detoxify chemical agents and deactivate explosive materials. Commonly used technologies include thermal and chemical treatments.
- **Post-treatment**—Operations that change the chemical nature of treatment waste streams to remove any remaining hazardous characteristics.
- **Effluent management**—Operations that change the physical nature of post-treatment waste streams to allow final disposition.

7.3.2 Alternative Technologies

The basis for any deployable system begins with the treatment technology. Available technologies can be categorized into five classes: thermal, chemical, biological, and irradiation, and hybrids that combine two or more technologies. These generic classes of treatment and some of their features are displayed in Table 7-1.

Some of these technologies have been or are in the process of being developed commercially. Generally, these systems are aimed at destroying industrial and hazardous wastes—only limited testing has been conducted on their applicability to chemical agents and explosives. In some cases, systems have been extensively used in commercial applications. In other cases, only limited bench-scale testing has been performed. A brief description of these commercial processes and their current state of development is shown in Table 7-2. As this table indicates, only two technologies have reached full-scale development with chemical agents: chemical reagent neutralization and incineration. Chemical reagent neutralization forms a part of the integrated system undergoing testing under the Assembled Chemical Weapons Assessment Program.

7.4 Transport of Non-Stockpile Chemical Warfare Materiel

If newly recovered non-stockpile CWM could not be stored at the recovery site or if a future treatment site is located at a distance from the storage or burial site, the items would have to be transported to the storage location. There would be restrictions on the possible locations of storage and treatment sites, as described in Section 1.6. CWM items could only be moved to a location within the state in which they were recovered or stored or to the nearest CWM stockpile storage facility that has the necessary permits to receive and store CWM. The Secretary of Defense must also determine that the movement is necessary, and public health and safety must be protected adequately during the transport operation.

Transporting CWM items from the recovery site to the off-property or storage location would be accomplished by truck and/or military aircraft in the same way as CWM items would be transported for off-property treatment under the proposed action (see Section 3.1.6).

Table 7-1. General Categories of Treatment Technologies

Class	Description		
Thermal	Use of heat to decompose chemicals.		
	Heating Methods: Direct, fuel-fired (combustion) Induction Plasma Arc Radiation	Equipment Configurations: Static furnace Rotary furnace Tunnel furnace Fixed bed reactor Fluidized bed furnace Molten media furnace Other configurations	Chemical Reactions: Oxidation Reduction (hydrogenolysis) Hydrolysis Reaction with sulfur
Chemical	The addition of reagents, sometimes with catalysts or activators at various temperatures and pressures, to detoxify chemicals. Includes electrochemical and photochemical technologies.		
	Hydrolysis Oxidation Reduction Dehalogenization	Alcoholysis Chlorolysis Digestion/dissolution Metal and metal oxide catalysis	
Biological	Use of biological organisms or enzymes to 'digest' biodegradable chemicals, converting them into less- or non-hazardous waste.		
Irradiation	Use of only radiation or light to decompose chemicals.		
Hybrids	Simultaneous integration of two or more treatment processes.		

Table 7-2. Applicability of Treatment Technologies to Non-Stockpile Chemical Warfare Materiel

Technology	Agent Use[b]	Scale with Agent[c]	Scale without Agent[d]	Explosives Treatment[e]	"Other" Munition Components[f]	Transportable[g]
Acid Digestion	Y	B	PS	N	Y	P
Adams Process Reaction with Sulfur	Y	B	PS	Y	P	N
Catalytic Oxidation	Y	B	C	P	P	Y
Chemical Reagent Neutralization[a]	Y	PS	C	Y	Y	Y
Direct, Fuel-Fired Combustion	Y	F	C	Y	Y	Y
Fixed-Bed Oxidation	Y	B	C	N	N	P
Fluidized-Bed Oxidation	N	—	C	Y	P	Y
Gas-Phase Chemical Reduction	Y	B	C	N	P	P
Hydrogenation Processes	N	—	C	N	P	N
Mediated Electrochemical Oxidation[a]	Y	PS	C	Y	P	P
Molten Metal Catalytic Extraction	Y	B	PS	P	P	N
Molten Salt Oxidation	Y	B	C	P	P	N
Plasma Arc Furnace[a]	N	—	C	P	P	P
Solvated Electron Reduction	Y	B	B	Y	P	Y
Steam Reformation[a]	N	—	C	P	P	Y
Supercritical Water Oxidation[a]	Y	B	C	P	P	Y
Wet Air Oxidation	N	—	C	P	P	P

[a] At least a part of the integrated system undergoing testing in the Assembled Chemical Weapons Assessment Program.
[b] Technology used to treat some type of chemical agent(s) in a specific study.
[c] Development status of the technology.
[d] Development status of the technology.
[e] Technology used to treat some type(s) of energetic material.
[f] Technically capable of treating munitions casing or other contaminated material based on current stage of development.
[g] Suitability of technology for implementation in a transportable system based on current stage of development.

B = bench-scale
C = commercial application
F = full-scale
N = no
P = judged to be possible based on existing evidence that the feature shows promise, but has not been demonstrated
PS = pilot-scale
Y = yes

The potential environmental impacts that could occur during the transport of CWM items are described in Section 5.5.

7.5 Accidental Release of Chemical Warfare Agents or Industrial Chemicals

Chemical warfare agents or industrial chemicals could be accidentally released to the environment during recovery or transport of CWM items, during long-term storage, or during future treatment. During recovery operations, an item could be dropped or accidentally detonate. During transport, an item could be dropped, leak, detonate, or an overpack could be breached in a transportation accident. While in storage, overpacked items could leak between inspections, be dropped during routine handling for maintenance, detonate if explosives became unstable, or be breached as a result of an external event that affected the storage building, such as an earthquake, tornado, or an airplane crash. During future treatment, an item could be dropped, leak, detonate, or breached as a result of an external event. The risks associated with the transportation and long-term storage of CWM items would be very low and are summarized in Appendix D. The risks of future treatment would not be known until a treatment system was developed. The possible environmental consequences of accidentally releasing chemical warfare agents or industrial chemicals is discussed below.

7.5.1 Burial Sites

Environmental management activities at CWM burial sites would be carried out by DoD organizations other than the NSCMP (Section 1.8) under the requirements of RCRA and CERCLA. Remediation decisions and activities at these sites are not under the control of the NSCMP and are independent of whether the Army implements the preferred alternative (described in Section 3.1) or the no-action alternative (described in Section 3.2). The responsible organizations at these sites would determine the possible environmental effects of accidentally releasing chemical agent and industrial chemicals and would consider these impacts in decisions about managing and remediating these sites.

7.5.2 Storage Sites

Chemical agent or industrial chemicals could be released to the environment at storage sites if an item is breached during handling or by an external event, such as an airplane crash into the storage building. Described below is the risk of an accidental release and the ecological and human health and safety effects that could result from a release.

7.5.2.1 Risk of Accidental Release

The accident risk assessment (Department of the Army, 1999b) assumed a 10-year continued storage period, as described in Appendix D. Long-term storage facilities may be located at the recovery location or elsewhere. Both the portable storage facility and igloo were considered as the storage facilities for the long-term storage option. A portable storage facility would be used for storage if the site does not have a suitable existing storage facility

available. It was assumed that an igloo would be used for the off-property storage facility. Additional unit operations would be involved if the recovered CWM were to be transported off-property for storage; risks for those operations would also apply to the off-property long-term storage option and should be considered as add-on risks. That is, the long-term storage risks would be in addition to the disposal risks that would eventually have to be incurred when the CWM is processed in the future. A summary of the risk characterizations for both the on-property and off-property long-term storage of CWM is presented in Table 7-3.

The portable long-term storage facility would be the same as the portable interim storage facility with longer storage duration (10 years). Small aircraft crashes are identified as the dominant risk contributors for the long-term storage unit operation for all site types. This event falls in frequency category C (Extremely Unlikely). Aircraft crash scenarios that involve the release of more volatile chemical agents (i.e., Sarin [GB] and phosgene) are assigned to severity category I for the three sizes of controlled areas considered. For site-types D, F, and G, this unit operation is assigned to the intermediate risk group. For site-types, A, C and E, the risk is assigned to the intermediate group for the smaller control area sizes, but drops down to the lower risk groups for the larger control areas. Site-type B is in the lower risk group for all of the control area sizes.

Earth-covered igloos are designed to withstand credible external events such as earthquakes, tornadoes, and aircraft crashes. Because of the high structural strength of the igloo, the crash of a small aircraft is not expected to breach an igloo or affect its structural integrity. The potential for a tornado-generated missile to penetrate an igloo is considered to be "Rare" based on its robust design. Igloos have been shown to withstand very large earthquakes without gross failure. Therefore, damage of stored CWM inside an igloo as a result of earthquakes, small aircraft crashes, or tornado-generated missiles would not be expected. Consequently, these scenarios are assigned to the lower risk group for all site types and controlled areas.

If the storage period were to be longer than 10 years, there would be a greater chance that the accident risk could increase because of the deteriorated state of the recovered CWM. This possibility is not reflected in the risk results.

7.5.2.2 Ecological Effects

The potential for chemical warfare agents or industrial chemicals in storage locations to cause ecological effects would be dependent upon the location of the storage facility, the nature and quantity of the chemical warfare agent or industrial chemical released, the mode of release, the fate, transport, and toxicity characteristics of the chemical released, and the contingency plans developed by the Army to eliminate or reduce the potential for exposure. The probability of a release event from storage locations would be quite small. However, should a release occur, the results probably would not differ significantly from those described in Sections 6.2.2 and 6.3.2. Those sections discuss the likelihood of exposure and the resulting ecological effects should a release occur.

Table 7-3. Summary of Risk Group Assignments for Long-Term Storage

Controlled Area around Storage Area (meters)	Unit Operation			
	Long-Term On-Property Storage[a]	Long-Term Off-Property Storage[b]	Transport and Handling[c]	Air Transport[d]
Site-Type A, CAIS Only (CAIS with Phosgene [CG])				
200	□	○	□	
1,000	○	○	□	○
2,000	○	○	□	
Site-Type B, CAIS Only (CAIS with Mustard [HD])				
200	○	○	○	
1,000	○	○	○	○
2,000	○	○	○	
Site-Type C, Non-Explosive Munitions (M70 bombs with Mustard [HD])				
200	□	○	□	
1,000	□	○	□	□
2,000	○	○	□	
Site Type D, Non-Explosive Munitions (M78 bombs with Phosgene [CG])				
200	□	○	□	
1,000	□	○	○	□
2,000	□	○	○	
Site-Type E, Explosive Munitions (155-mm projectiles with Mustard [HD])				
200	□	○	□	
1,000	□	○	□	
2,000	○	○	□	
Site-Type F, Explosive Munitions (155-mm projectiles with Sarin [GB])				
200	□	○	□	
1,000	□	○	□	
2,000	□	○	□	
Site-Type G, Chemical Samples (Ton container with Sarin [GB])				
200	□	○	□	
1,000	□	○	□	□
2,000	□	○	□	

– upper risk group □ – intermediate risk group; ○– lower risk group

[a] Storage facility is located on the military installation or other property where the items were recovered. Storage would be in a portable facility.

[b] Storage facility is not located on the military installation or other property where the items were recovered. Storage would be in an igloo.

[c] Transportation and handling between interim storage facility and military airfield and between destination military airfield and off-property storage facility.

[d] Controlled area designation does not apply to air transport.

CAIS– Chemical agent identification set

Differences between the probabilities of exposure as described in Section 6 and those resulting from the no-action alternative arise primarily from the length of time munitions are stored relative to the preferred alternative and the slightly decreased amount of handling of munitions compared to the processes associated with the mobile treatment systems. In general, however, impacts to the environment would be similar to those described in Section 6.

Spills of fuel, oil, or lubricants from equipment operating at the storage site would have the potential to contaminate groundwater. The chance is small, however, because the volume that could be spilled would be small and standing operating procedures would be in place to contain any spill and remove any contaminated soil from the site before groundwater could be affected.

7.5.2.3 Human Health Effects

The potential for chemical warfare agents or industrial chemicals to cause injury or death would depend on both the probability of an accidental release and the likelihood of exposure after the release. As discussed in Section 7.5.2.1 and the accident risk assessment (Department of the Army, 1999b), the probability of release would be very small. However, in the event of an accidental release, the likelihood of exposure would depend on the location of the storage facility, the nature and quantity of the chemical warfare agent or industrial chemical released, the ways by which the chemical might be released, the environmental fate and transport of the released chemical, and contingency plans developed by the Army to eliminate or reduce the potential for exposure. For most of the chemical agents and industrial chemicals, these factors would be expected to result in a very small probability of exposure. Exposure probability may be greater for the volatile chemicals and for some of the persistent environmental degradation components.

Sections 6.2.3 and 6.3.3 discuss the likelihood of exposure to chemical warfare agents and industrial chemicals, respectively, after an accidental release. Those sections also discuss the acute and chronic effects that would be expected from actual exposures to toxic concentrations of these chemicals. In addition, those sections assess the likelihood that an accidental release would result in high enough concentrations of air, water, soil, and other ground surfaces to produce these effects in exposure to individuals. Finally, those sections identify specific chemical warfare agents and industrial chemicals that would have the greatest potential to cause acute and/or chronic effects from exposures after an accidental release.

7.5.3 Treatment Sites

Since the type of treatment system or systems that would be developed in the future is not known, the risk of releasing chemical agent or industrial chemicals at a treatment site cannot be determined at this time. Similarly, the environmental impacts of such releases cannot be analyzed until the circumstances of the releases are known. The Army would conduct appropriate risk, safety, and environmental reviews in the future when a system was ready for final development.

7.5.4 Transport of Non-Stockpile of Chemical Warfare Materiel

Transporting CWM items to a location for long-term storage or from storage to a treatment site would be carried out in the same way as transporting an item under the preferred alternative (see Section 3.1.6). The possible environmental impacts of releasing chemical agent or industrial chemicals during transport are described in Sections 6.2 and 6.3.

7.6 Adverse Impacts that Cannot Be Avoided

Long-term storage of non-stockpile CWM items and treatment using a technology or method developed in the future would have some adverse environmental and socioeconomic impacts that could not be avoided, even if mitigating measures were implemented. The extent of impacts would be site-specific and would depend on the activities required at a storage site and the treatment method used in the future. Unavoidable impacts would likely be modest or minor at the storage site. The impacts of future treatment cannot be determined at this time. Unavoidable impacts of storage are described below.

Setup and operation of a new storage facility would require land that would be used until the facility was no longer needed. During this time, the site would be mostly unavailable as wildlife habitat. Soils could be affected permanently if not restored during site closure. Sediment in runoff from the site could increase some during site preparation and site closure. Access to economically important minerals under or near the treatment site could be eliminated or restricted.

Operation of vehicles and equipment at the storage site and aircraft for transporting CWM to a storage or treatment location and for other transportation activities would generate noise and release some pollutants into the air.

Hazardous and other solid and liquid wastes could be generated that would require disposal.

Use of the operating site for other activities would be precluded for the duration of the storage period. Use and/or access restrictions could be placed on adjacent properties while CWM items are in storage at the location.

Should chemical agent or industrial chemicals be released accidentally at the storage site or during transportation of items to an off-site storage location, some short-term acute effects could occur to human health and the environment.

7.7 Irreversible and Irretrievable Commitments of Resources

Operating a storage site for non-stockpile CWM would result in some commitment of resources that would be irreversible and irretrievable. These would be energy, chemicals and materials, landfill capacity, and economic and human resources.

Energy in the form of fuels and electricity used directly or indirectly to operate the facilities and associated vehicles and support systems would be an irretrievable commitment of these nonrenewable resources. This energy would be unavailable for other uses.

Various chemicals and materials could be required for maintaining CWM items safely in storage. Chemicals and materials that would not be recycled or reused would be irreversibly committed to this activity because most wastes from maintenance would likely be disposed of permanently in landfills or by other permanent destruction methods as required under RCRA, CERCLA, and other federal, state, and local statutes and regulations.

Placing solid and hazardous wastes generated from storage operations in solid and hazardous waste landfills would have the practical effect of irreversibly committing this landfill space to wastes from this activity. This space would be unavailable for wastes from other sources.

Capital, workers, and equipment used during the storage period and for transporting non-stockpile CWM would be and irreversible commitment of these resources t o this activity, making them unavailable for other purposes.

7.8 Relationship Between Short-Term Uses of Man's Environment and the Maintenance and Enhancement of Long-Term Productivity

Long-term storage of CWM items until treated in the future would continue the risk to human health and safety and the environment from accidental release of the hazardous contents as long as the items remain in storage. This risk would only end at some time in the future when the item would be treated and the wastes disposed.

Disposal of the wastes generated from maintenance activities during storage would result in the long-term commitment of land with restricted surface and possibly subsurface uses.

7.9 Cumulative Impacts

The cumulative impacts from the long-term storage of the CWM considered in this environmental impact statement would include the impacts from the storage itself, plus the impacts from the ultimate treatment of the CWM being stored, plus the impacts from various other ongoing or future planned actions that could occur in the vicinity of any site used for long-term storage of CWM, any site used in ultimately treating the stored CWM, and/or any site used to manage wastes generated from the storage and ultimate treatment of the CWM. These impacts would all be very site-specific. Furthermore, the treatment technologies, processes, and methods that would ultimately be used are not known at this time, and consequently their impacts cannot be analyzed at this time. Thus, the cumulative impacts of long-term storage of the CWM cannot be meaningfully analyzed at this time.

Section 8

List of Preparers and Reviewers

This draft programmatic environmental impact statement was prepared for the Product Manager for Non-Stockpile Chemical Materiel. Preliminary analyses and drafts were prepared by Horne Engineering Services, Inc., and its subcontractors. Mitretek Systems, Inc., completed the analyses and prepared the draft programmatic environmental impact statement.

Preparers

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Experience: Twenty-four years of experience in the area of environmental analysis and assessment. Led and contributed to the preparation of environmental impact statements, environmental assessments, and environmental studies, for such concerns as fossil fuel and nuclear power plants, wastewater treatment and disposal, oil and gas exploration and production, pipeline construction and operation; dredging and dredged material disposal; recreational development of coastal areas, realignment of military installations and activities, and demolition of chemical warfare agent production facilities.
Responsibility: Project leader. Responsible for overall integration of document. Prepared geology, groundwater, and ecological environment sections and contributed to the remainder of the document.

Name: IVAN J. BOYER
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M.S., Toxicology, University of Rochester School of Medicine and Dentistry, 1983
M.S., Biology, Boston College, 1979
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Experience: Twenty-four years of experience, including conducting hazard characterization and risk assessment of chemicals, serving as risk-assessor/reviewer for several closing Air Force Bases, and providing advisory opinions on the toxicology and potential hazard of chemical contaminants in foods.
Responsibility: Analyses of human health effects findings in Sections 6 and 7.

Name: THOMAS C. CAIN
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Education: B.S., Chemical Engineering, concentration in chemistry, math, and English, Tennessee Technological University, 1983
Experience: Fifteen years of experience during which he conducted verification and validation of a computer simulation model of the Tooele Chemical Agent Disposal System, as well as a preliminary risk assessment of the safety, health, and environmental risks of the five proposed alternative (to incineration) technologies. Has extensive experience in the manufacture of solid rocket motors and other conventional explosives.
Responsibility: Prepared Appendix B (Non-Stockpile Chemical Warfare Materiel) and Appendix G (Other Treatment Technologies and Systems), and contributed to Appendix C (Transportable Treatment Systems).

Name: DAVID J. CLEAVES
Affiliation Mitretek Systems, Inc.
Education: M.E., Nuclear Engineering, University of Virginia, 1994
U.S. Navy Nuclear Power School, 1979
B.S.E., Chemical Engineering, Princeton University, 1978
Experience: Twenty-one years of experience that includes service in the U.S. Navy and private-sector assignments. Conducted a variety of risk analyses characterizing (1) the safety and risk implications associated with the design and placement of a mustard thaw facility at Aberdeen Proving Ground, (2) transportation alternatives for the on-site movement of munitions at various sites, and (3) the risks associated with long-term chemical reactions, corrosion effects, and thermal effects on ton containers.
Responsibility: Contributed to the analysis of risk of accidental release found in Sections 6 and 7.

Name: ALAN J. GOLDFARB
Affiliation Mitretek Systems, Inc.
Education: Ph.D., Chemical Engineering, University of Maryland, 1977; University of Delaware Extension Division, Graduate Study in Statistics; State University of New York at Buffalo, Graduate Study in Chemical Engineering
B.Ch.E., The City College of the City University of New York, 1962
Experience: Thirty-seven years of experience that includes conducting an independent safety and environmental performance evaluation of the mobile systems designed to demilitarize chemical agent identification sets and non-explosively configured munitions, and automated destination analysis. Provided technical support to the U.S. Army Program Manager for Chemical Demilitarization with respect to the addition of a carbon filter on the Pollution Abatement System for the incinerator emissions from the chemical demilitarization facilities and verification and validation of a simulation of the chemical demilitarization facilities. Actively providing support to the Army chemical warfare munitions demilitarization program since 1986.
Responsibility: Prepared information on the MMD-1 for Appendix C.

Name: STUART A. HAUS
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Experience: Thirty years experience in a wide variety of work programs involving environ mental analysis, risk analysis, environmental regulatory development, air quality analysis, environmental compliance, regulatory impact analysis, and chemical demilitarization programs. Prepared environmental impact statements, environmental assessments, and environmental studies in such areas as alternative chemical demilitarization technologies, demolition of chemical warfare agent production facilities, non-stockpile chemical munitions, hazardous waste management, energy development, and water-related construction projects. Helped develop the RCRA hazardous waste management regulations and the Superfund Hazard Ranking System.
Responsibility: Prepared information regarding air quality, waste management, public health and safety, and cumulative impacts throughout the document.

Name: CATHERINE F. JACOBSON
Affiliation Mitretek Systems, Inc.
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Experience: Nine years of experience in the field of toxicology. Evaluated the potential risks to human reproduction and prenatal development of exposure to various environmental contaminants and industrial chemicals. Developed approaches to use bioavailability data for human health risk assessment and assisted in the analysis of anatomical and physiological parameters affecting absorption of compounds from the gastrointestinal tract.
Responsibility: Co-wrote Appendix E (Human Toxicity of Non-Stockpile Chemicals).

Name: CRAIG S. KORALEK
Affiliation Mitretek Systems, Inc.
Education: B.Ch.E., Chemical Engineering, Georgia Institute of Technology, 1969
Experience: Thirty years of experience in air pollution assessment and environmental planning. Developed emissions inventories and toxic release inventory (TRI) reports for both government and private industry. Determined air quality impacts from point and area sources in the U.S. and Europe. Prepared air permit applications for industrial point sources. Evaluated cost and effectiveness of air pollution abatement systems to reduce human exposure to toxic air pollutants. While working for a state air pollution agency, conducted enforcement inspections of pulp and paper mills, power plants, and other facilities.
Responsibility: Prepared air quality analyses in Sections 4, 5, and 7.

Name: AMY L. LAVIN
Affiliation Mitretek Systems, Inc.
Education: Ph.D., Toxicology, University of Rochester, 1998
M.S., Toxicology, University of Rochester, 1997
B.Sc., with distinction, Toxicology and Human Biology, University of Toronto, 1992
Experience: Six years of experience in the field of toxicology. Assessed the potential risk to human health associated with TCE exposures based on an analysis of epidemiological data, chronic animal test results, and data relevant to the mechanism of carcinogenicity. Compared humans and animal models of postnatal development for the development of pediatric pharmaceuticals.
Responsibility: Co-wrote Appendix E (Human Toxicity of Non-Stockpile Chemicals).

Name: DAISY M. LIGON
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Experience: Thirty-one years of experience in the areas of systems engineering analysis, decision analysis, probabilistic risk assessment, environmental analysis, and regulatory analysis of chemical and nuclear operations. Responsible for managing the risk and safety assessment tasks in support of the Chemical Demilitarization Program.
Responsibility: Prepared Appendix D (Summary of Accident Risk Assessment).

Name: BARRY S. NASH
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Education: M.S., Environmental Sciences, University of Virginia, 1980
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Experience: Twenty years experience in the area of environmental analysis and review. Background includes aquatic ecology and experience with the design and interpretation of a variety of sampling protocols for hazardous waste investigations. Familiar with a number of techniques for environmental risk assessment and evaluation, including the U.S. EPA's Hazard Ranking System, the Department of Defense's Relative Risk Evaluation process, and the Food and Drug Administration's process for evaluating environmental impacts of new drugs manufacturing. Performed analysis and review of Global Climate Change issues, use of high resolution imagery for environmental management, and Archive Search Report for Air Combat Command.
Responsibility: Prepared environmental analyses found in Sections 4, 6, and 7.

Name: KRISHANS S. RAGHUVEER
Affiliation Mitretek Systems, Inc.
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M.S., Organic and Physical Chemistry, University of Texas, 1974
M.Sc., Organic Chemistry, Indian Institute of Technology, 1972
B.Sc., Chemistry, Physics, and Mathematics, Bangalore University, 1970
Experience: Seventeen years of experience in the field of synthesis and analytical chemistry and environmental remediation. Background includes laboratory management and operation for environmental analysis and applications in demilitarization chemistry, on-site characterization of hazardous waste for transportation and disposal purposes, and waste treatability studies.
Responsibility: Prepared Appendix F (Environmental Fate of Non-Stockpile Chemicals).

Name: RICHARD P. RHOADS
Affiliation Mitretek Systems, Inc.
Education: Candidate for Professional Masters in Environmental Engineering, University of Maryland College Park, 1998
B.S., Chemical Engineering, Bucknell University, 1991
Experience: Eight years of experience providing technical assistance and advice in analyzing contractor proposed methods for alternative demilitarization of chemical weapons. Participated in the design review, acceptance, and startup of a 30-gallon bench-scale neutralization system. Managed the implementation of ISO Guide 25 quality requirements into 12 government and contractor laboratories at ERDEC performing research for the Alternative Technologies Program.
Responsibility: Prepared analysis of RRS for Appendix C.

Name: BRANT E. SMITH
Affiliation Mitretek Systems, Inc.
Education: B.A., Environmental Science, University of Virginia, 1979
Experience: Twenty years of experience, with expertise in environmental impact analyses, program evaluation, regulatory analysis, environmental chemistry, risk management, instrumentation systems design and implementation, effects research, and quality assurance.
Responsibility: Prepared analyses of traffic, utilities, land use, socioeconomic characteristics, and environmental justice found in Sections 4, 5, and 7.

Name: PAOLO TRINCHIERI
Affiliation Mitretek Systems, Inc.
Education: M.B.A., Virginia Polytechnic Institute and State University, in progress
B.S.E., Chemical Engineering, University of Pennsylvania, 1995
Experience: Four years experience in environmental compliance and the analysis and management of hazardous waste for transportation in accordance with EPA and DOT standards.
Responsibility: Description of the transportable treatment systems and support facilities and equipment, as well as the alternatives.

Name: **DONALD R. PHOENIX, PH.D.**
Affiliation: Horne Engineering Services, Inc.
Education: Ph.D., Biology/Ecology, University of Pennsylvania, 1976
B.A., Biology, University of Pennsylvania, 1968
Experience: Thirty years experience managing major multidisciplinary programs, including site investigations; remedial action plans; radioactive, hazardous, and mixed waste characterizations; site selection studies; preparation of environmental impact analyses and NEPA documents; preparation of licenses and permits; preparation of risk assessments; delineation of wetlands and wetland restoration; terrestrial and aquatic ecological studies; and fate and effect chemical analyses.
Responsibility: Project manager and principal reviewer for preliminary analyses and drafts.

Name: **IRWIN J. SAMEC**
Affiliation: Horne Engineering Services, Inc.
Education: M.U.R.P., Urban and Regional Planning, Michigan State University, 1972
B.A., Sociology, Illinois Wesleyan University, 1970
Experience: Twenty-eight years experience in preparing and managing environmental assessments and impact statements of nuclear, waste management and treatment, and energy facilities; conducting multidisciplinary environmental siting studies; preparation of environmental compliance documents; preparation of environmental and socioeconomic characterization studies; preparation of transportation and water resource studies; and conducting public involvement and participation activities.
Responsibility: Task Manager responsible for providing technical direction, guidance, and review in preliminary analyses and drafts.

Name: **ANDREW P. BLASCO**
Affiliation: Horne Engineering Services, Inc.
Education: M.S., Nuclear Chemistry, Ohio State University, 1963
B.S., Chemistry, Loyola College, 1959
Experience: Thirty-nine years experience in chemical warfare munitions and environmental chemistry, multidisciplinary research, development systems acquisition management, operational tests and analyses, chemical weapons safety and surety, and chemical demilitarization plant operations.
Responsibility: Initial analyses and preliminary drafts.

Name: **CHARLES J. DOBROSKI, JR.**
Affiliation: Roy F. Weston, Inc.
Education: M.S., Marine Biology, University of Delaware, 1978
B.S., Entomology and Applied Ecology, University of Delaware, 1973
Experience: Twenty years of experience in risk assessment and environmental impact assessment, including extensive analyses conducted pursuant to CWA, CERCLA/SARA, RCRA, NEPA, TSCA, and FIFRA.
Responsibility: Initial analyses and preliminary drafts.

Name: SEAN B. DONAHUE
Affiliation: Tetra Tech, Inc.
Education: M.S., Biology, West Virginia University, 1987
B.S., Mathematics, Fairmont State College, 1985
B.S., Biology, Fairmont State College, 1985
Experience: Thirteen years experience in risk assessment, environmental impact assessment, and biostatistical analysis primarily related to human health and ecological risk assessment under CERCLA/SARA, RCRA, CWA, and NEPA.
Responsibility: Initial analyses and preliminary drafts.

Name: REECE C. EDMONDS, JR.
Affiliation: Horne Engineering Services, Inc.
Education: DBA (Candidate), Business Administration, Nova University
M.S., Business Administration, Boston University, 1981
B.S., Business Management, University of Tampa, 1978
Experience: Twenty-three years experience in management of hazardous, nuclear, chemical, and explosive disposal operations, including experience with chemical munitions storage, shipment, and disposal; U.S. Army chemical surety officer and subject matter expert for chemical accident or incident response and assistance.
Responsibility: Initial analyses and preliminary drafts.

Name: SUNIL S. GODBOLE
Affiliation: Roy F. Weston, Inc.
Education: M.S., Environmental Science/Toxics Option, NJ Institute of Technology, 1990
B.S., Chemical Engineering, University of Bombay, India, 1987
Experience: Twelve years experience in risk assessment of contaminated properties and Superfund sites, solid/hazardous waste management, selection of remedial technologies and process treatments, RCRA compliance, and industrial toxicology.
Responsibility: Initial analyses and preliminary drafts.

Name: EDWARD GROTH
Affiliation: Horne Engineering Services, Inc.
Education: Graduate Studies, Business Administration, Central Michigan University - Aberdeen, 1990-1992
B.S., Business Administration, Upper Iowa University, 1985
Experience: Twenty-four years experience managing environmental, safety and compliance projects, including contingency planning and emergency response, safety, and risk management for chemical and explosive munition operations; safety, security, and environmental compliance for toxic chemical and explosive emergency disposal operations; RCRA; and assessment and permit application for disposal operations.
Responsibility: Initial analyses and preliminary drafts.

Name: **JOHN H. GURLEY, JR.**
Affiliation: Horne Engineering Services, Inc.
Education: B.S., Biology, Gettysburg College, 1988
Experience: Ten years experience as an environmental scientist in the preparation of environmental assessments for projects at Army, Air Force, and commercial installations; natural resources management; hydropower licensing; environmental permitting; rare, threatened, and endangered species analysis; and sustainable development.
Responsibility: Initial analyses and preliminary drafts.

Name: **ANDREW HAINES**
Affiliation: Horne Engineering Services, Inc.
Education: M.S., Ecology, University of Tennessee, 1982
B.S., Wildlife and Fisheries Science, University of Tennessee, 1977
Experience: Seventeen years experience in planning, conducting, and managing environmental assessments and impact studies for transportation facilities, power plant development, hazardous waste sites, resource recovery facilities, military base operations, and construction-related projects.
Responsibility: Initial analyses and preliminary drafts.

Name: **DANIEL HOLLAND**
Affiliation: Roy F. Weston, Inc.
Education: Post-Baccalaureate Courses, Drexel University, 1992; University of Akron, 1982
B.S., Meteorology, Pennsylvania State University, 1981
Experience: Thirteen years of professional meteorological/air quality dispersion modeling experience, prevention of significant deterioration ambient air/meteorological programs, air dispersion modeling studies, and field emissions testing.
Responsibility: Initial analyses and preliminary drafts.

Name: **ANDREA O'GRADY, CHMM**
Affiliation: Horne Engineering Services, Inc.
Education: M.S. (Candidate), Environmental Management, University of Maryland
B.S., Biology, Pennsylvania State University, 1990
Experience: Eight years experience in environmental compliance, hazardous waste management, regulatory analysis, environmental permitting, and environmental training and management; preparation of environmental documents for the U.S. Army Chemical Stockpile Disposal Program, NSCMP, and Alternative Technology Program; preparation of RCRA permit applications and other waste management plans.
Responsibility: Initial analyses and preliminary drafts.

Name: **JENNIFER B. SEERY**
Affiliation: Roy F. Weston, Inc.
Education: M.A., Biology, Boston University, 1994
B.A., Environmental Biology (Chemistry minor), Colby College, 1993
Experience: Environmental biology and chemistry, human and ecological assessments, toxicological profiles, qualitative and quantitative analytical techniques, statistical data analysis, aquatic toxicology, nutrient modeling and remediation of coastal and freshwater systems.
Responsibility: Initial analyses and preliminary drafts.

Name: JEFFREY THIELKER
Affiliation: Horne Engineering Services, Inc.
Education: M.S., Ocean Engineering, University of Massachusetts, 1977
B.S., Agricultural Engineering, University of Delaware, 1975
Experience: Twenty-three years experience in multidisciplinary environmental investigations and restoration projects for the U.S. Army (Toxic and Hazardous Materials Agency and Corps of Engineers); multimedia field operations; analytical interpretation of technically unique circumstances; innovative technical approaches and methods for the disposal of hazardous and toxic wastes; BRAC; FUDS; CERCLA; RI/FS; and RCRA.
Responsibility: Initial analyses and preliminary drafts.

Name: ROBERT O. WARWICK, PH.D.
Affiliation: Roy F. Weston, Inc.
Education: Ph.D., Pharmacology, Purdue University, 1975
M.S., Pharmacology, Purdue University, 1972
B.S., Pharmacy, Philadelphia College of Pharmacy and Science, 1970
Experience: Ten years experience in technical management of human health risk assessments. Technical review and coordination of human health risk assessments. Fourteen years of academic experience in teaching undergraduate and graduate courses in pharmacology and toxicology.
Responsibility: Initial analyses and preliminary drafts.

Name: MICHAEL T. WERNER, J.D.
Affiliation: Roy F. Weston, Inc.
Education: J.D., Law, Syracuse University, 1982
M.S., Biology, Clarion University, 1976
B.S., Biology, Ursinus College, 1974
Experience: Eighteen years experience in many aspects of environmental analysis and resource management planning and policy analysis, including preparation of environmental impact statements and risk assessments.
Responsibility: Initial analyses and preliminary drafts.

Name: TIMOTHY J. WOODS
Affiliation: Roy F. Weston, Inc.
Education: B.S., Public Health: Environmental Health, West Chester University, 1990
Experience: One year experience in risk assessment. Fields of competence include human health risk assessments, data evaluation, soil sampling, and data collection.
Responsibility: Initial analyses and preliminary drafts.

Name: YUEWEI ZHU, PH.D., P.E.
Affiliation: Horne Engineering Services, Inc.
Education: Ph.D., Environmental Engineering, Lehigh University, 1992
M.S., Environmental Engineering, Lehigh University, 1990
B.S., Environmental Engineering, Tongji University, 1983
Experience: Fifteen years experience in environmental engineering and research specializing in risk assessment, computer modeling, Phase I/Phase II site investigations, water/wastewater pollution control processes and facility design, waste minimization, groundwater remediation design, hazardous waste management, and treatment processes for heavy metals and toxic chemicals.
Responsibility: Initial analyses and preliminary drafts.

Government Reviewers

Name: LEONARD C. ROWE, SR.
Affiliation: U.S. Army Product Manager for Non-Stockpile Materiel
Education: M.S., Chemical Engineering, Vanderbilt University, 1985
M.S., Physical Chemistry, University of North Carolina, 1977
B.S., Chemistry, Wofford College, 1975
Experience: Fifteen years experience in various Army chemical weapons demilitarization programs, including incinerator test and trial burns, RCRA permitting activities, and chemical agent monitoring. Work has involved developing Programmatic Plans, Monitoring Systems, Assessment Systems, Rapid Response Systems, and Munitions Management Device — Version 1. Managed the development and fielding of the Mobile Munitions Assessment System.
Responsibility: Army Manager for preparing the programmatic environmental impact statement.

Name: THOMAS D. FORSYTHE, PH.D.
Affiliation: Tennessee Valley Authority/Non-Stockpile Chemical Materiel Project
Education: Ph.D., Ecology, Michigan State University, 1978
M.S., Fisheries & Wildlife, Michigan State University, 1974
B.S., Biology/Chemistry, St. Cloud State University, 1972
Experience: Twenty-five years experience in ecological research, natural resource management, environmental education, economic development, and environmental impact analysis.
Responsibility: NEPA specialist providing technical support to the Army.

Name: **G. LYNN HOLT, DRPH, CIH, CSP**
Affiliation: Tennessee Valley Authority/Non-Stockpile Chemical Materiel Project
Education: Doctor of Public Health, University of Alabama at Birmingham, 1993
M.S., Industrial Hygiene, Texas A&M University, 1974
B.S., Chemistry, University of North Alabama, 1970
Experience: Twenty-eight years experience in all aspects of environmental and occupational health, including risk assessment of CERCLA and RCRA sites; preparation of hazardous waste site sampling and health protection plans; health and safety oversight of the demolition of a variety of toxic manufacturing facilities; development and implementation of comprehensive health and safety programs; and preparation and presentation of extensive environmental health and safety training.
Responsibility: Risk Assessment Specialist providing technical support to the Army.

Name: **JOSEPH T. JOHNSON**
Affiliation: Tennessee Valley Authority/Non-Stockpile Chemical Materiel Project
Education: M.S., Biology, University of South Florida, 1976
B.A., Marine Science, University of the South, 1965
Experience: Twenty-eight years experience in water chemistry and aquatic toxicology. Team leader responsible for environmentally related research and development and environmental document preparation, licensing and regulation compliance for TVA's Technology Advancement Division. Extensive experience in environmental assessment and the preparation of environmental reports and impact statements.
Responsibility: Review of technical documents relating to the PEIS. Provide assistance to the Army in implementing NEPA and coordinating preparation of NEPA related documentation.

Name: **DALE V. WILHELM**
Affiliation: Tennessee Valley Authority/Non-Stockpile Chemical Materiel Project
Education: M.S., Meteorology, South Dakota School of Mines and Technology, 1974
B.S., Mathematics, South Dakota School of Mines and Technology, 1973
Experience: Twenty-three years experience in preparing and managing multidisciplinary environmental reviews, including managing environmental assessments and impact statements for power production facilities, industrial and commercial facilities, land and water resources management activities, and uranium mining and milling facilities. TVA Corporate, NEPA and Liaison Office and NEPA Administration Team Leader.
Responsibility: Primary NEPA advisor to Army PEIS Project Manager, responsible for PEIS oversight, NEPA compliance, Government consultation and coordination in providing technical review, guidance, and direction in the preparation of the PEIS.

Distribution List

This list is maintained by the Program Manager for Chemical Demilitarization's Public Affairs Office at (410) 436-3629.

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Acronyms

µm	micrometer
AC	Hydrogen cyanide
ACGIH	American Conference of Government Industrial Hygienists
AIHA	American Industrial Hygiene Association
AR	Army Regulation
ARAR	Applicable or relevant and appropriate requirement
ASTM	American Society for Testing Materials
BACT	Best Available Control Technology
BBC	Bromobenzyl cyanide
BIAE	Bulk Item Accessing Equipment
BZ	3-quinuclidinyl benzilate
CA	Bromobenzyl cyanide
CAIS	Chemical agent identification set
CC	Comparison compound
CCTV	Closed-circuit television
CDMH	Chlorodimethylhydantoin
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CG	Phosgene
CHA	Cyclohexylamine
CK	Cyanogen chloride
CN	Chloroacetophenone
CNB	Chloroacetophenone in benzene and carbon tetrachloride
CNS	Chloroacetophenone and chloropicrin in chloroform
CO	Carbon monoxide
CWA	Chemical warfare agent
CWC	Chemical Weapons Convention
CWM	Chemical warfare materiel
DA PAM	Department of the Army Pamphlet
DAAMS	Depot ambient air monitoring station
dB	decibel
DCDMH	Dichlorodimethylhydantoin
DCIS	Digital control and instrumentation system
DEA	Diethanolamine
DIMP	Diisopropyl methylphosphonate
DIPAE	2-diisopropylamino ethanol
DIPAES	2-(diisopropylamino) ethyl sulfide
DIPAMS	Chloromethyl-2-(diisopropylamino) ethyl sulfide
DIPTU	1,3-diisopropylthiourea
DIPU	1,3-diisopropylurea
DM	Adamsite
DMH	5,5-dimethylhydantoin

DNL	Day-night sound level
DoD	Department of Defense
DoDI	Department of Defense Instruction
DP	Diphosgene
DRE	Destruction and removal efficiency
EA 2192	S-(2-diisopropylaminoethyl) methylphosphonothiotic acid
ECBC	Edgewood Chemical and Biological Center
EDC	Environmental degradation component
EDS	Explosive Destruction System
EG	Ethylene glycol
EMPA	Ethyl methylphosphonic acid
EO	Executive Order
EOC	Emergency operations center
EPCRA	Emergency Preparedness and Community Right-To-Know Act
EPZ	Emergency planning zone
FAA	Federal Aviation Administration
FR	Federal Register
FUDS	Formerly used defense sites
GA	Tabun
GB	Sarin
GC/MS	Gas chromatograph/mass spectrometer
GD	Soman
H	Levinstein mustard
HAP	Hazardous air pollutant
HBESL	Health-Based Environmental Screening Levels
Hcl	Hydrogen chloride
HD	Distilled mustard
HETM	N-(2-hydroxyethyl) thiomorpholine
HF	Hydrogen fluoride
HL	Mustard-lewisite mixture
HMTA	Hazardous Materials Transportation Act
HN	Nitrogen mustard
HN-1	Nitrogen mustard 1
HN-2	Nitrogen mustard 2
HN-3	Nitrogen mustard 3
HS	Sulfur mustard
HT	Mustard-T mixture
HUD	Department of Housing and Urban Development
HVAC	Heating, ventilating, and air conditioning
I/O	Input/output
IBC	Intermediate bulk container
IC_{50}	Incapacitates 50 percent of an exposed population
IHF	Interim holding facility
IMPA	Isopropyl methylphosphonic acid

K_{OW}	Octanol-water partition coefficient
L	Lewisite
LAER	Lowest Achievable Emission Rate
LD_{50}	Lethal to 50 percent of an exposed population
LDR	Land disposal restriction
Leq	Equivalent sound level
m^3	cubic meter
MACT	Maximum Achievable Control Technologies
MCL	Maximum contaminant level
MCLG	Non-zero maximum contaminant level goal
MEA	Monoethanolamine
MEDCOM	U.S. Army Medical Command
MEK	Methyl ethyl ketone
mg	milligram
min	minutes
mm	millimeter
MMAS	Mobile Munitions Assessment System
MMD-1	Munitions Management Device–Version One
MMD-2	Munitions Management Device–Version Two
MPA	Methyl phosphonic acid
MTV	Munitions Treatment Vessel
NA	Not applicable
Na_2CO_3	Sodium carbonate
Na_2MPA	Disodium methylphosphonate
NaAEMPA	Sodium O-(2-aminoethyl) methylphosphonate
NAAQS	National Ambient Air Quality Standard
NaCl	Sodium chloride
NaEMPA	Sodium O-ethylmethylphosphonate
NaF	Sodium fluoride
NaOH	Sodium hydroxide
NaThiol	Sodium 2-diisopropylaminoethanethiolate
NCP	National Contingency Plan
ND	Not detected
NESHAP	National Emission Standard for Hazardous Air Pollutant
NIOSH	National Institute of Occupational Safety and Health
NMFS	National Marine Fisheries Services
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NRT	Near–real-time
NSCMP	Non-Stockpile Chemical Materiel Project
NSPS	New Source Performance Standards
O_3	Ozone
OSHA	Occupational Safety and Health Administration

Pb	Lead
PC	Personal computer
$PD_{1\%}$	Plume distance to one percent lethality
PD_{ND}	Plume distance to no deaths
PEIS	Programmatic Environmental Impact Statement
PM_{10}	Particulate matter less than 10μm in diameter
$PM_{2.5}$	Particulate matter less than 2.5μm in diameter
PMNSCM	Project Manager for Non-Stockpile Chemical Materiel
PMPA	Pinacolyl methylphosphonic acid
POP	Performance-oriented packaging
PPE	Personal protective equipment
ppm	parts per million
PRG	Preliminary remediation goal
PS	Chloropicrin
PSD	Prevention of Significant Deterioration
RCRA	Resource Conservation and Recovery Act of 1976
RCT	Reagent Charge Tank
RRS	Rapid Response System
SARA	Superfund Amendments and Reauthorization Act of 1986
SBCCOM	Soldier and Biological Chemical Command
SIP	State Implementation Plan
SO_2	Sulfur dioxide
SRC	Single-round container
TBA	Tributylamine
TC	Training Circular
TCLP	Toxicity characteristic leaching procedure
TDG	Thiodiglycol
TLV	Threshold limit values
TM	Technical Manual
TNT	Trinitrotoluene
TOC	Total organic carbon
tpy	tons per year
TSDF	Treatment, storage, and disposal facility
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UV	Ultraviolet
Chromium VI	Hexavalent chromium
VX	Nerve agent
VX-N-MEA	N-2-hydroxyethyl methylphosphoramidate
Wt%	Percent by weight

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Volume II
Appendices

Draft Programmatic
Environmental Impact Statement

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Transportable Treatment Systems for Non-Stockpile Chemical Warfare Materiel

U.S. Department of the Army
Project Manager for Non-Stockpile Chemical Materiel
Aberdeen Proving Ground, Maryland

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Appendix A

Public Comments and Responses

Reserved for public comments and responses

Appendix B

Non-Stockpile Chemical Warfare Materiel Considered in the Programmatic Environmental Impact Statement

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Appendix B

Non-Stockpile Chemical Warfare Materiel Considered in the Programmatic Environmental Impact Statement

Only some types of non-stockpile chemical warfare materiel (CWM) are considered in the programmatic environmental impact statement. The non-stockpile CWM are categorized into three classes:

- Chemical munitions
- Storage containers
- Chemical agent identification sets (CAIS)

These three classes are described below. The status of these items in burial sites or in storage is also discussed.

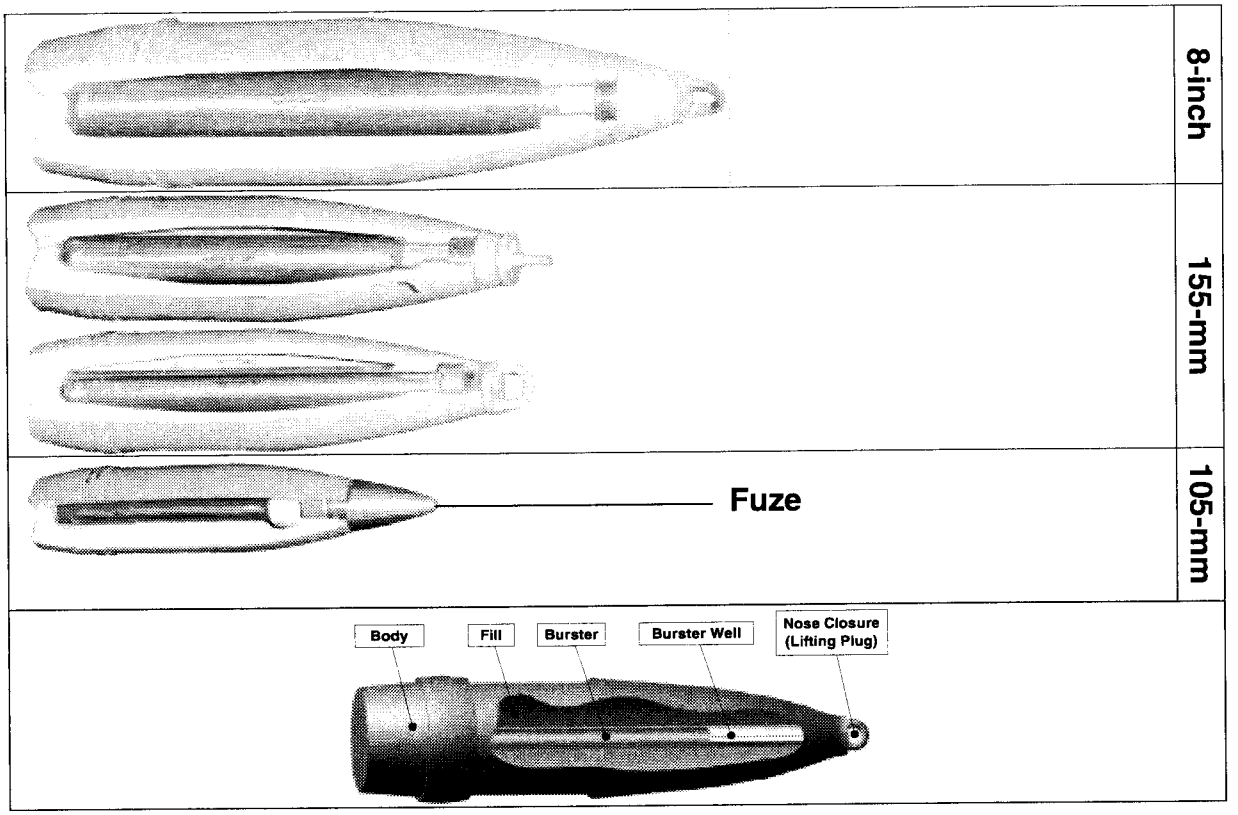
B.1 Munitions

Chemical munitions consist of a chemical reservoir with a sequence of explosive devices, called the "explosive train," to rupture the reservoir, disseminating the fill. Typically, an explosive train consists of a fuze with booster, supplementary charge, and burster. Munitions configurations are described by category in the following subsections.

B.1.1 Projectiles

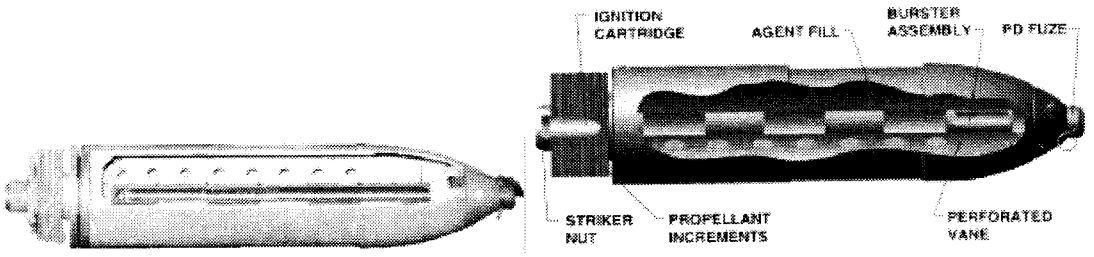
Projectiles consist of artillery and mortar shells.[1] Non-stockpile CWM projectiles are expected to range from 75 to 203 mm (3 to 8 inches) nominal diameters. Projectile component assemblies may be glued, staked, pinned, or welded. In storage, small-caliber projectiles that can be lifted by one person (typically <50 lb) have fuzes in place, while larger caliber projectiles, too heavy to lift easily, have lifting lugs instead of fuzes (unless recovered as "duds"). When artillery shells are configured with the casing and propulsive charges or when mortar shells have the aft propulsive charge installed, they are referred to as cartridges. Cartridge configurations are expected to be an infrequent occurrence for non-stockpile CWM. Examples of artillery shells are shown in Figure B-1 and a mortar cartridge (i.e., with propulsive charge) is shown in Figure B-2.

[1] The difference between chemical artillery and mortar shells is negligible. Artillery shells are fired from breech-loaded artillery (i.e., mechanically transported cannons, howitzers, etc. like those on ships, tanks, etc.) while mortars are transported manually and their shells are fired by loading from the muzzle.



Note: Not to Scale.

Figure B-1. Typical Chemical Artillery Shells



Note: Propulsion charge (propellant increments and ignition cartridge) on aft end not normally present.

Figure B-2. Typical Chemical Mortar Shell
(4.2-inch M2/M2A1 for Rifled Bore Mortar Shown)

B.1.2 Aerial Bombs, Submunitions, and Bomblets

Aerial bombs were dropped from aircraft and range in weight from 14 to 454 kilograms (30 to 1,000 pounds). Illustrated examples of some aerial bombs are shown in Figure B-3.

The payload of some larger munitions consisted of a number of submunitions or "bomblets", small munitions ranging in size from about 25 to 100 mm (1 to 4 inches) in diameter. Submunitions and bomblets frequently have explosive components. An illustrated example of a bomb with submunitions is shown in Figure B-4.

Bombs are typically transported and stored without explosive components (bursters, boosters, fuzes, or submunitions). Explosive components are generally only installed on bombs just before loading onto an aircraft. Explosively configured bombs are expected to be an unlikely occurrence as non-stockpile CWM, due only to a misfiring during testing.

B.1.3 Rockets

Rockets or missiles are fully assembled, self-propelled munition that may have a single chemical reservoir or bomblets (bomblets are not normally present while in storage). Chemical rockets range in size from 60-mm (2.36-in) diameter bazooka rounds to the Honest John Rocket with a 762-mm (30-in) diameter and 364 bomblets. The propellants used in rocket motors are shock and heat sensitive, making handling more hazardous than other munitions. Figure B-5 illustrates the exterior configuration of some non-stockpile rockets and shows an annotated cutaway of the 115-mm Chemical Rocket, which also exists in the stockpile.

B.1.4 Spray Tanks

Spray tanks or spray apparatuses ranged in size from portable units carried by one person up to tanks weighing approximately 900 kg (1 ton). These tanks were not designed to use explosives to disseminate chemicals, but may have explosive components designed to either open valves or eject the spray tank from the aircraft. An illustration of the TMU-28 spray tank is shown in Figure B-6.

B.1.5 Manually Delivered

Manually delivered munitions are small items that are placed by hand or delivered by an individual soldier.

B.1.5.1 Placed

Placed munitions are delivered to a target by hand and include landmines and smoke pots. These munitions usually contained from 3.8 to 19 liters (1 to 5 gallons) of liquid so they would be transportable by one person. Explosive components, when used, were either installed or stored in the same container used to store the munition. As with other munitions, fuzes, or activators were not typically installed until ready for delivery. An example of a chemical landmine is shown in Figure B-7. Smoke canisters typically used a slow burning material to cause chemical fills to form a smoke.

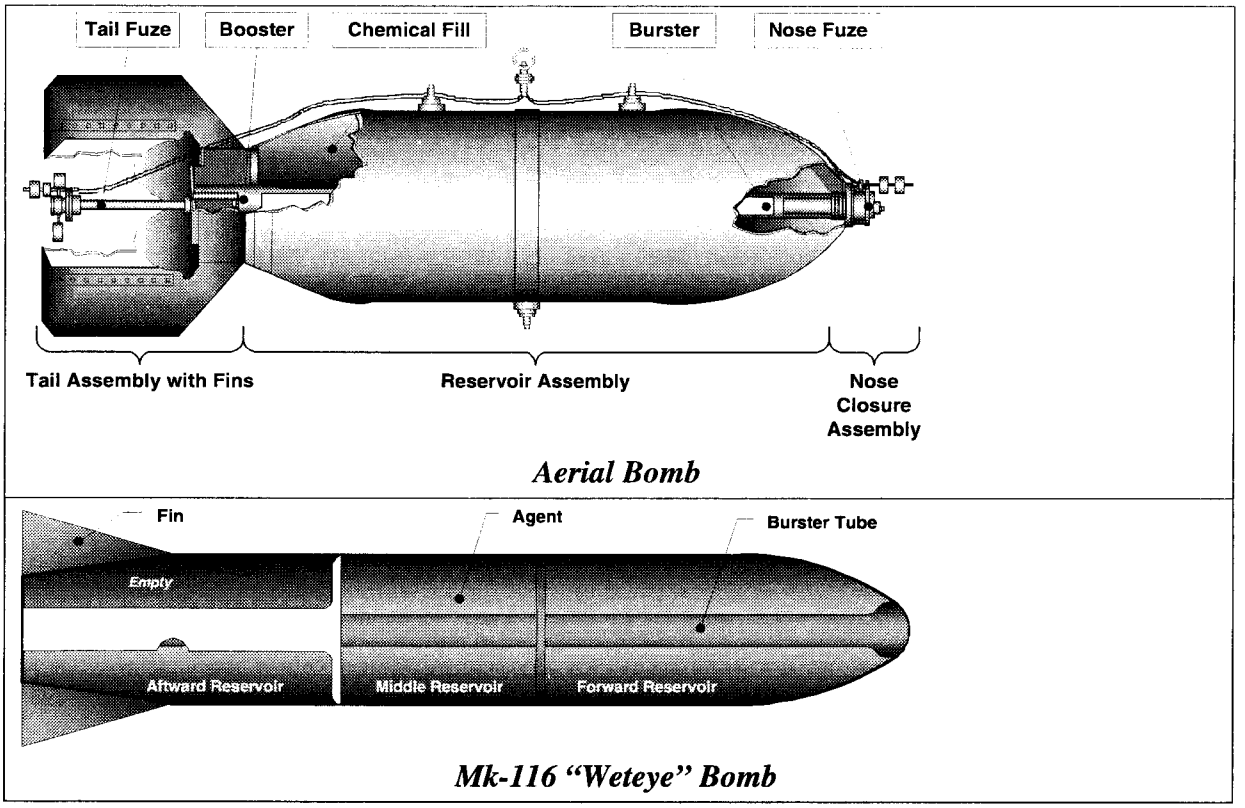


Figure B-3. Aerial Bombs

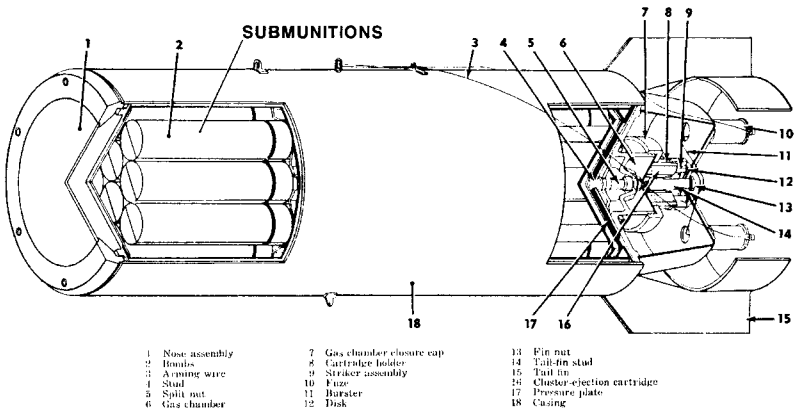


Figure B-4. Aerial Bomb with Submunitions

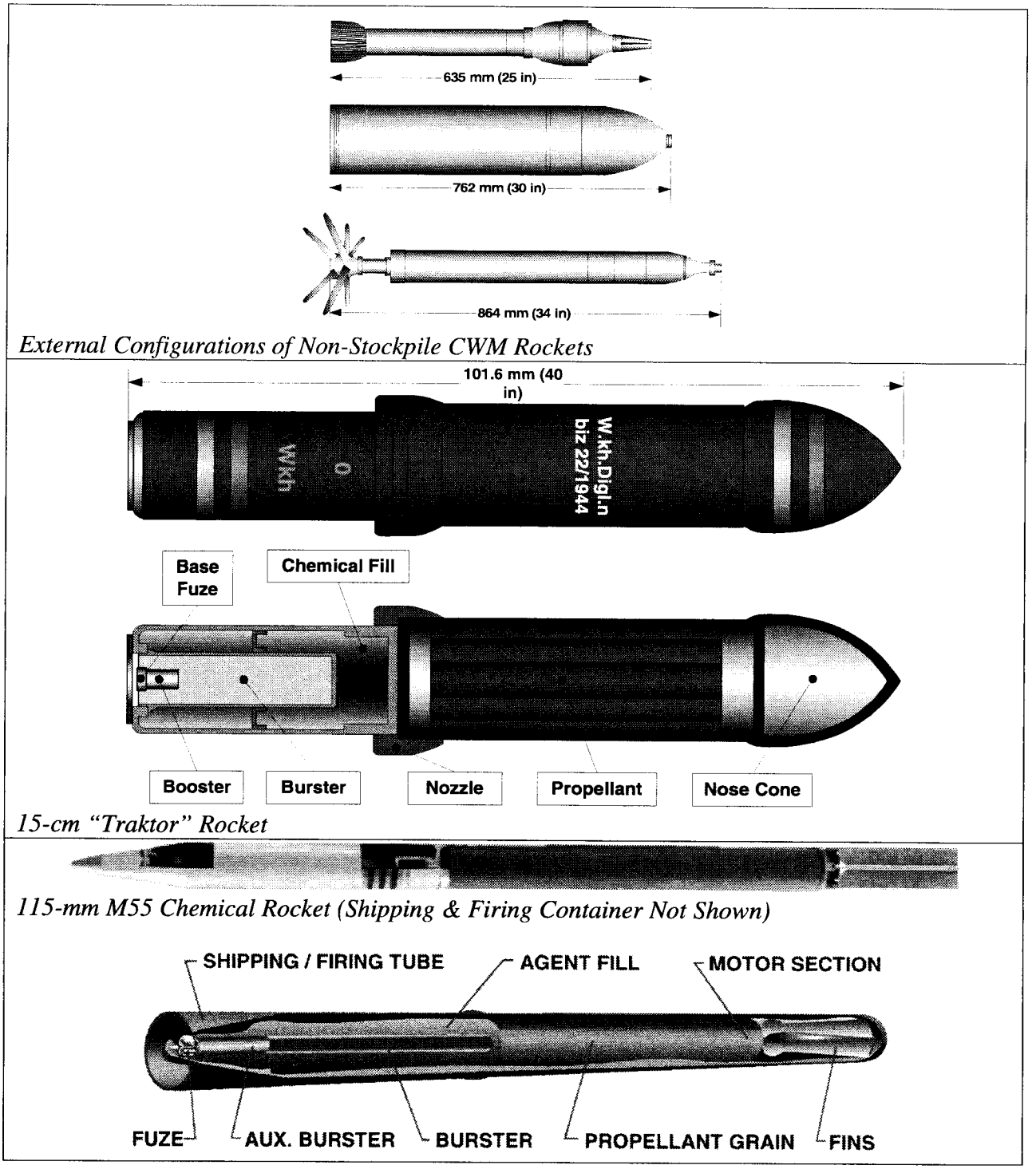


Figure B-5. Typical Chemical Rockets

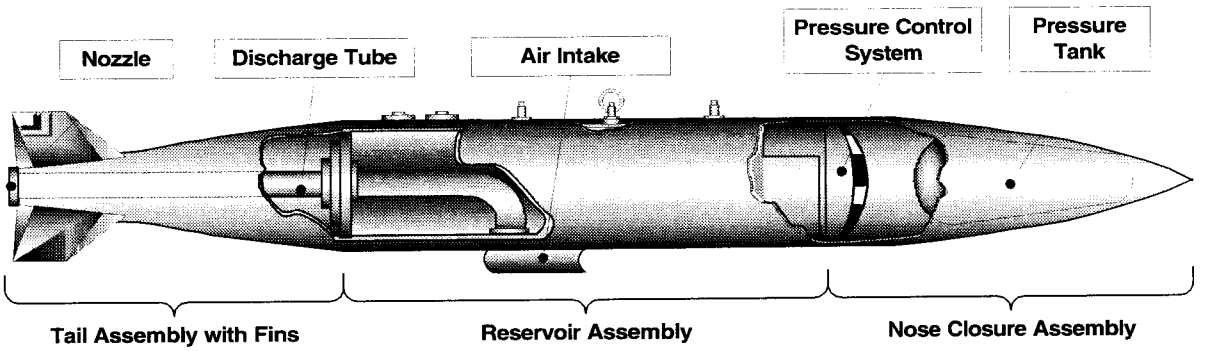


Figure B-6. Aerial Spray Tank

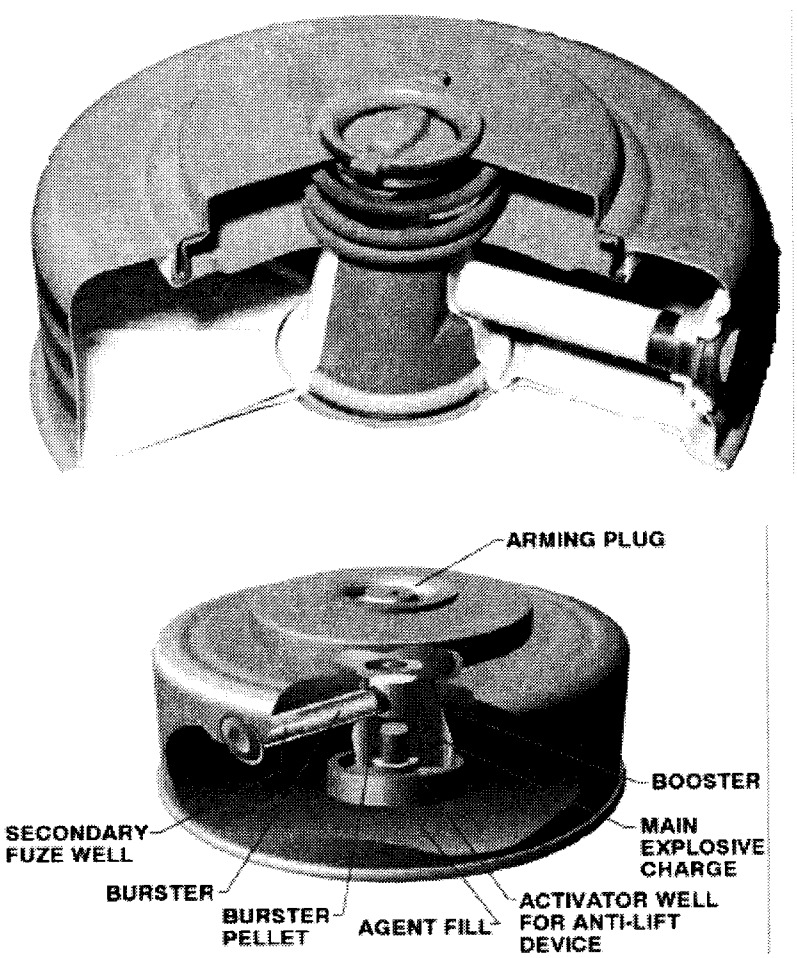


Figure B-7. Typical Chemical Landmine

B.1.5.2 Thrown

Thrown munitions are manually thrown or ejected by a small explosive charge and include grenades, ejection smoke canisters, and the like. These could be explosive, smoking, or frangible. Frangible, or breakable, munitions were designed to rely on the force of gravity and their impact with the ground to cause the munition case to rupture. The chemical in the munition would then be disseminated by splashing or evaporation.

B.2 Storage Containers

Another class of non-stockpile CWM is containers of chemical agents. Several different types of containers have been used to store or transport chemical agent. Types of containers that have been used include glass ampoules and bottles, drums, metal shipping bottles meeting U.S. Department of Transportation specifications of various sizes, and up to a "1-ton container", which is a commercial metal cylinder used to transport chlorine gases and other compounds. Examples of storage containers are shown in Figure B-8.

B.3 Chemical Agent Identification Sets

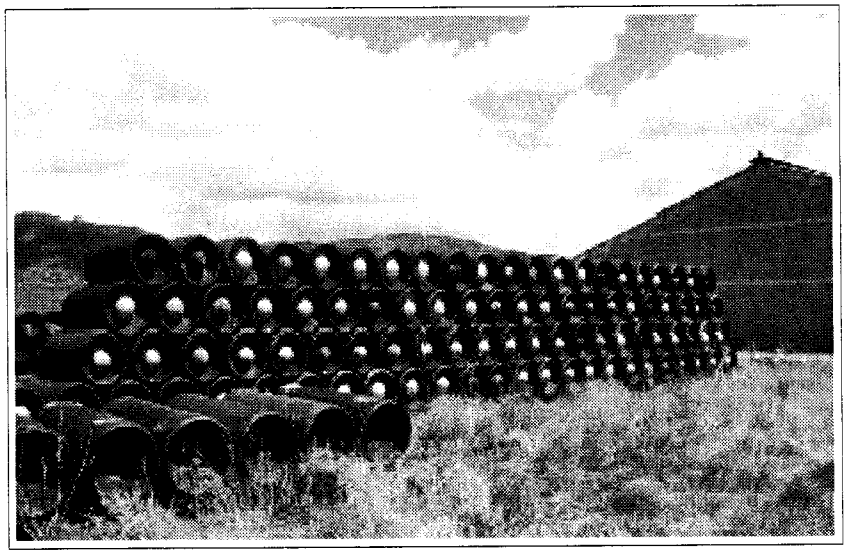
Chemical agent identification sets (CAIS) are not munitions but, rather, are training materials previously used by troops to identify and decontaminate chemical agent or industrial chemicals (see Figure B-9). Use of these items for training was discontinued in 1969. CAIS contain only small quantities of chemical agent or industrial chemicals.

One major variety of CAIS was an instructional "sniff set" that contained agent-impregnated charcoal. This set was used indoors to instruct military personnel on how to recognize the odors of chemical agents. The set contained only small amounts of chemical agent.

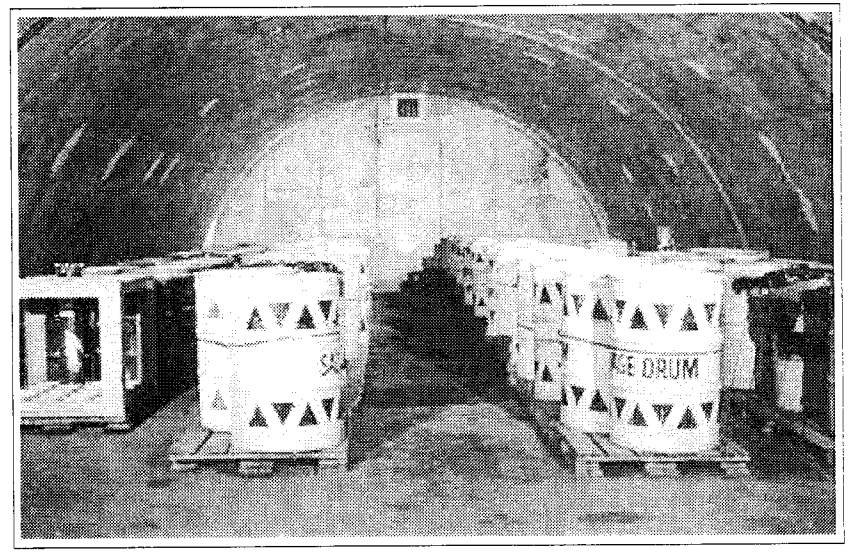
A second major variety of CAIS, designed for use outdoors, consisted of chemical agent (pure or in solution) in sealed Pyrex® tubes. The gas tubes would be detonated, creating a chemical agent cloud. Soldiers thoroughly attired in personnel protective equipment would then try to identify the agent using chemical agent detection kits (e.g., absorbent tubes). These CAIS tubes typically contained more agent than the instructional sniff sets.

A third major variety of CAIS contained approximately 110 milliliters (3.5 ounces) of mustard agent. These sets were used for decontamination training. Terrain or equipment was purposely contaminated with mustard. The soldiers were taught how to put on the correct protective clothing and then how to decontaminate the area or equipment.

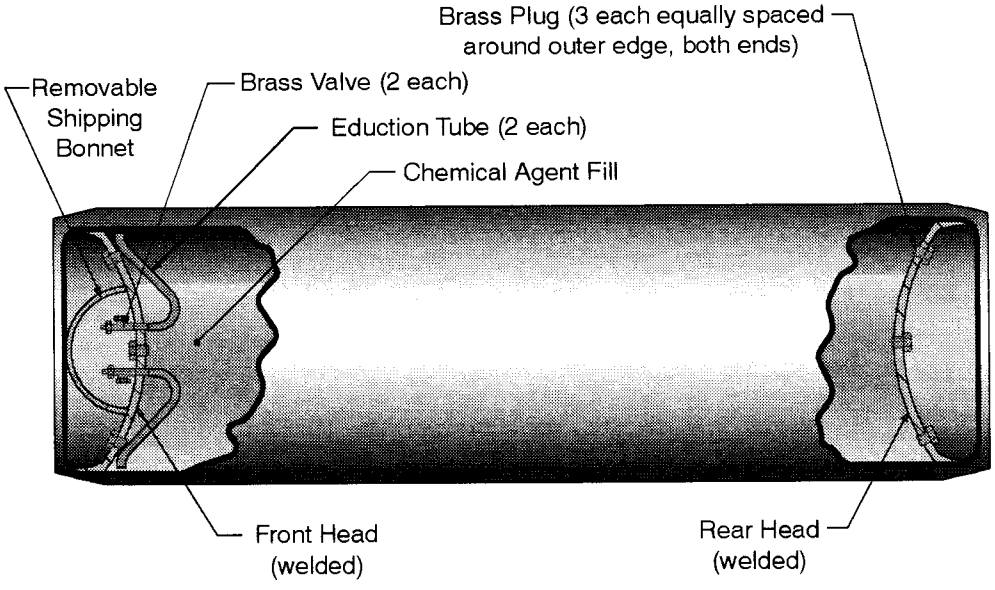
The chemical agent and industrial chemicals in CAIS are contained in ampoules or bottles in small quantities. In the original CAIS, these ampoules or bottles were packaged in metal cans, which were then packaged in steel drums, in wooden boxes, or in heavy metal shipping containers called "pigs."



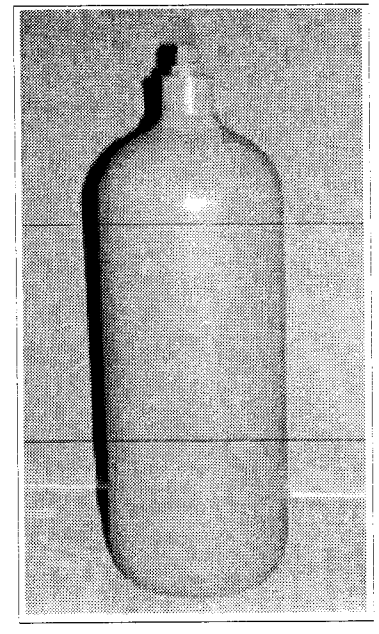
TON CONTAINERS



DRUMS IN TEMPORARY STORAGE



TON CONTAINER (bulk storage)



DEPARTMENT OF TRANSPORTATION BOTTLE

Figure B-8. Typical Chemical Containers

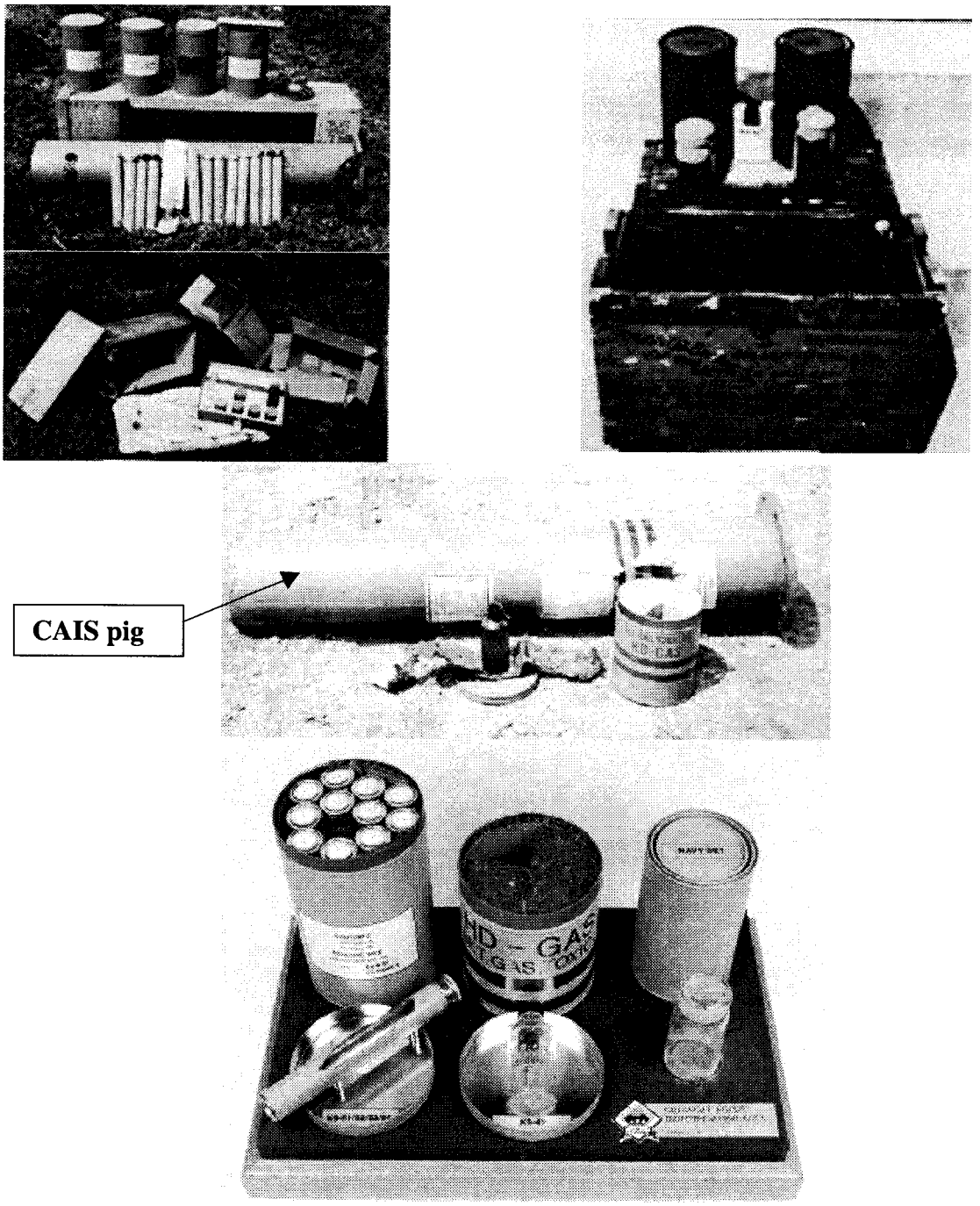


Figure B-9. Chemical Agent Identification Sets (CAIS)

B.4 Buried Chemical Warfare Materiel

In the previous category descriptions, reference is made to a munition's various configurations. In order to identify the likelihood of possible non-stockpile CWM configurations, it helps to understand the possible storage and field configurations, as well as the potential disposal practices.

There are typically only two configurations applicable: logistical and deliverable. The difference between these two configurations is critical to how they are likely to be found as non-stockpile CWM.

- ***Logistical*** refers to the storage configuration such as palletized, boxed, containerized, etc. Most non-stockpile CWM munitions are unlikely to be in their original storage configuration. Some munitions do not have all components of the explosive train installed until in the delivery configuration. For example, some munitions are stored with the central burster assembly in place but without the fuze. Such munitions are referred to as "burstered". Burstered munition are safer than fuzed munition, but are still considered explosively configured.
- ***Deliverable*** refers to the field configuration of the munition as it is ready to deliver to a target (or, in the case of placed munition, placed at a target). The two types of deliverable configurations would be fuzed and fired or fuzed and not fired. Once the entire explosive train is installed, it is called "fuzed". Before or during delivery the safety feature is disabled, the fuze is activated and the munition is "live."

CWM were usually in the safest explosive configuration possible and usually burned or chemically neutralized prior to deliberate burial for disposal. CWM may be or have been buried as shown below in Figure B-10 and may currently exist as shown in Figure B-11.

Typically, chemical munitions were stored or handled in the safest configuration allowable. Explosive components (bursters, boosters, fuzes, etc.) are supposed to be removed before disposal/burial. Fuzed munitions could have been buried, but it is unlikely that they were intentionally buried "live."

Some definitions of burial sites are as follows:

- Small Quantity—Less than 1000 items
- Large Quantity—Greater than 1000 items
- Non-Explosive—No potential for explosive components or propellants
- Explosive—Potential for explosive components or propellants

Non-stockpile CWM also includes munitions that may have been fired, dropped, or placed on test ranges but failed to function (i.e., "duds"). These munitions would most likely contain explosive components. "Duds" pose the greatest risk to excavation and recovery operations since they are expected to be found in the "live" condition. Fuzed munitions are

Figure B-10. Chemical Munitions Land Burial (World War II)

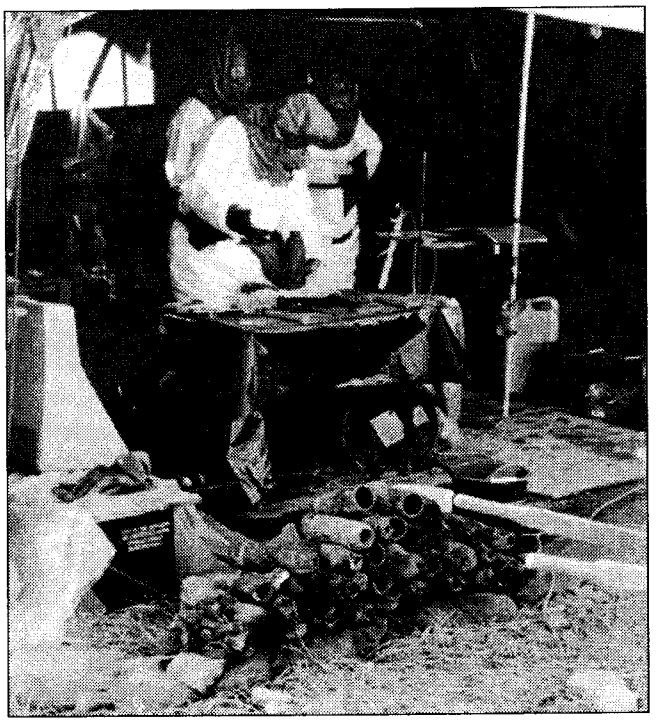
Figure B-11. Munitions Residue from Past Agent Disposal Action

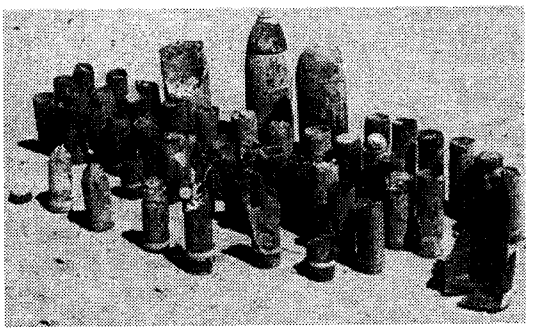
considered unexploded ordnance and must be rendered safe before packaging for storage and subsequent disposal as non-stockpile CWM. In many instances, fuzes are considered unsafe and must be removed before storing. As such, recovered munitions placed into storage are very unlikely to have fuzes present.

B.5 Recovered Chemical Warfare Materiel

Recovered CWM (Figure B-12) consists of items recovered from firing and test-range clearing operations and burial sites and placed in storage. CWM items that cannot be transported or stored due to unacceptable risks are destroyed on site using emergency destruction procedures. CWM determined to be safe are overpacked (i.e., placed into a container with packing material as appropriate) and stored for subsequent disposal as non-stockpile CWM. CWM operations related to excavation, recovery, and containerizing (for storage) are not under the jurisdiction of the Non-Stockpile Chemical Materiel Project (NSCMP). The NSCMP is only responsible for disposal of the recovered CWM.

Recovered CWM currently being stored on an interim basis consist of (1) CAIS items, (2) chemical munitions without explosive components, and (3) chemical munitions with explosive components.





Munitions

CAIS Ampoules

Figure B-12. Recovery Operations and Recovered CWM

Appendix C

Transportable Treatment Systems

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Appendix C

Transportable Treatment Systems

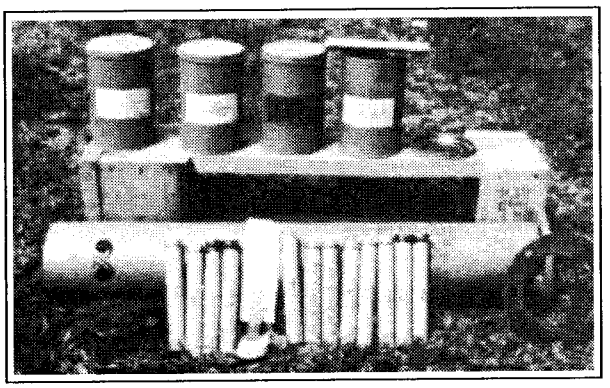
C.1 Introduction

The Army is developing four types of integrated transportable treatment systems for non-stockpile chemical materiel. These systems are summarized in Section 2 and described in more detail in this appendix. The systems are: the Rapid Response System (RRS), which will be used for chemical agent identification sets (CAIS); the Munitions Management Device–Version One (MMD-1), which will be used for chemical munitions without explosive components and for small containers of chemicals with diameters of not more than 8 inches (20 centimeters); the Munitions Management Device–Version Two (MMD-2), which will be used for CWM munitions with and without explosive components, shipping and storage containers, and chemical samples; and the Explosive Destruction System (EDS) which would primarily be used for explosive chemical weapons which are not safe to handle and at locations with only a few chemical warfare materiel items.

C.2 Rapid Response System

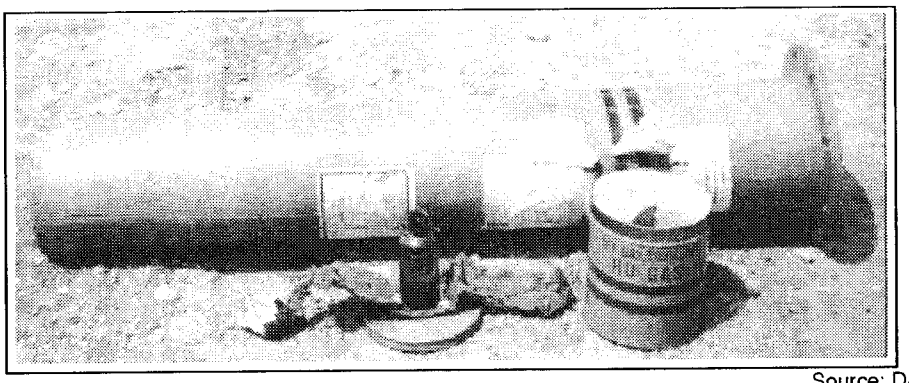
The Rapid Response System (RRS) is a transportable chemical treatment system that has been developed to safely access and treat chemical agent identification set (CAIS) items containing chemical agent. CAIS were produced in large quantities (approximately 110,000) and in various configurations during their years of manufacture and use (1928 to 1969). They were distributed at Army military installations for the purpose of training service personnel in the identification of actual chemical warfare agents and the proper actions to take upon identification. CAIS items consist of (1) sealed PYREX® tubes or ampoules containing chemical agents (e.g., sulfur mustard [HD], nitrogen mustard [HN], and Lewisite) and industrial chemicals (e.g., cyanogen chloride, phosgene, chloropicrin, chloroform); (2) glass bottles containing neat (or pure) mustard agent; and, (3) "sniff sets"—wide-mouth glass jars containing either a small amount of mustard agent or Lewisite adsorbed onto granulated charcoal. CAIS ampoules or bottles are packaged in metal cans that are packed in pigs (heavy-walled metal shipping containers), steel drums, or wooden boxes. Figure C.2-1 shows examples of CAIS.

CAIS ampoules and bottles recovered from burial sites have often been found buried outside of their original shipping containers. In some instances, the shipping container was buried with the contents intact, but the container was corroded to the point where it could not be used for storage or transportation. In most cases, the ampoules or bottles that are recovered need to be repackaged into different shipping containers that meet U.S. Department of Transportation (USDOT) specifications for shipment. The number of bottles or ampoules contained in a shipping container varies based on the number of CAIS items recovered at a



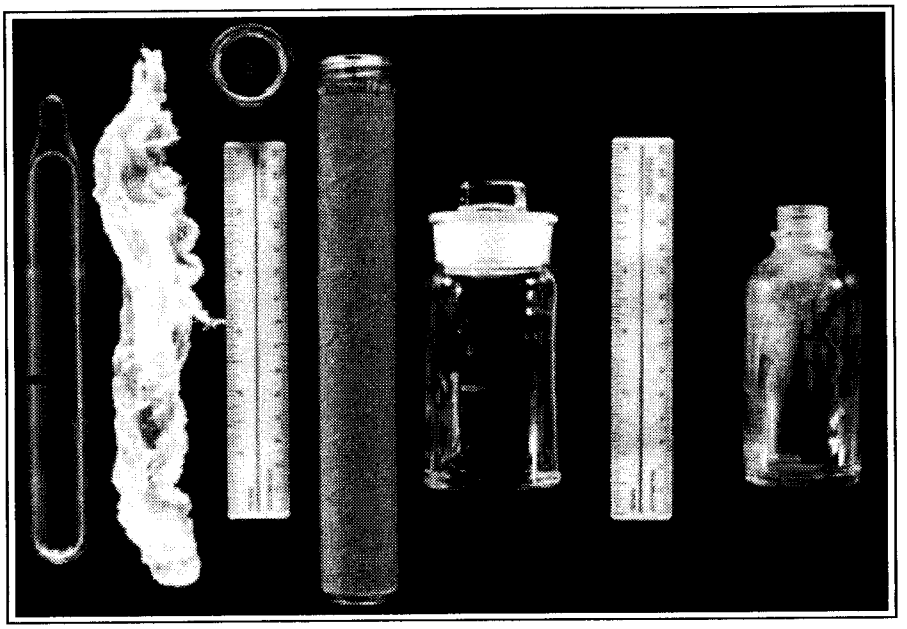
Source: DA and USMC, 1994; DA, 1995a

Chemical Agent Identification Set



Source: DA, 1995a

Chemical Agent Identification Set Metal Pig and Contents



Agent Identification Set Ampoule and Bottles

Figure C.2-1. Examples of Chemical Agent Identification Sets

site. Containers currently in storage hold from 1 to 48 ampoules or bottles (Department of the Army, 1996a; Department of the Army, 1997a).

C.2.1 Components of the Rapid Response System

The RRS main facilities will consist of an operations trailer and a utility trailer (see Figure C.2-2). The operations trailer will contain all of the process equipment and instrumentation required for RRS operations. The utility trailer will contain a primary and a backup generator that will enable the RRS to operate without an outside power source. The primary means of deploying the trailers to a site will be by road transport, although the RRS trailers will be capable of being transported by military aircraft for long-distance deployment. A mobile analytical support platform (MASP), which will reside on a transportable trailer, will accompany the RRS and provide the necessary analytical equipment for determining treatment effectiveness and for analyzing air-monitoring samples.

Other support facilities could accompany the operations and utility trailers and the MASP depending on the availability of such facilities at a site. These other support facilities will include a supply trailer containing ancillary equipment, including personal protective equipment (PPE); a personnel decontamination station; an Interim Holding Facility (IHF) for storage of non-stockpile CWM; and a command post for administrative personnel. Figure C.2-3 depicts a conceptual site layout of the RRS with its other support facilities. A temporary waste storage area and a parking area will also be needed if such facilities were not available at the site. Although the RRS will be designed to operate in the open, RRS operations could be conducted in an existing and appropriate building or in an environmental enclosure which will provide an additional level of vapor containment between the operations trailer and the ambient environment.

The operations trailer, where the CAIS items will be processed, will contain a three-station glovebox: an airlock station, an unpack station, and a neutralization station (Figure C.2-4). Figure C.2-5 presents a process flow diagram for the RRS. The CAIS will enter the glovebox system on a cart track into the airlock station, the doors will be closed, and negative pressure will be achieved before operations continue. In the unpack station, the CAIS items will be removed from the containers, identified using a spectrophotometer, and segregated. CAIS items containing industrial chemicals will be repackaged according to military and USDOT specifications for shipment to an approved hazardous waste treatment, storage, and disposal facility (TSDF). In the neutralization station, the treatment of CAIS items containing chemical agent will occur in a nominal 1-gallon (3.8-liter) reactor vessel. Liquid and solid wastes will be removed from the RRS operations trailer in separate drums and will be shipped to a TSDF for final treatment.

The following subsections describe the various integrated components and systems which will be located in the operations and utility trailers based on the RCRA permit application for the RRS system tests (Department of the Army, 1996a) and the RRS system test plan

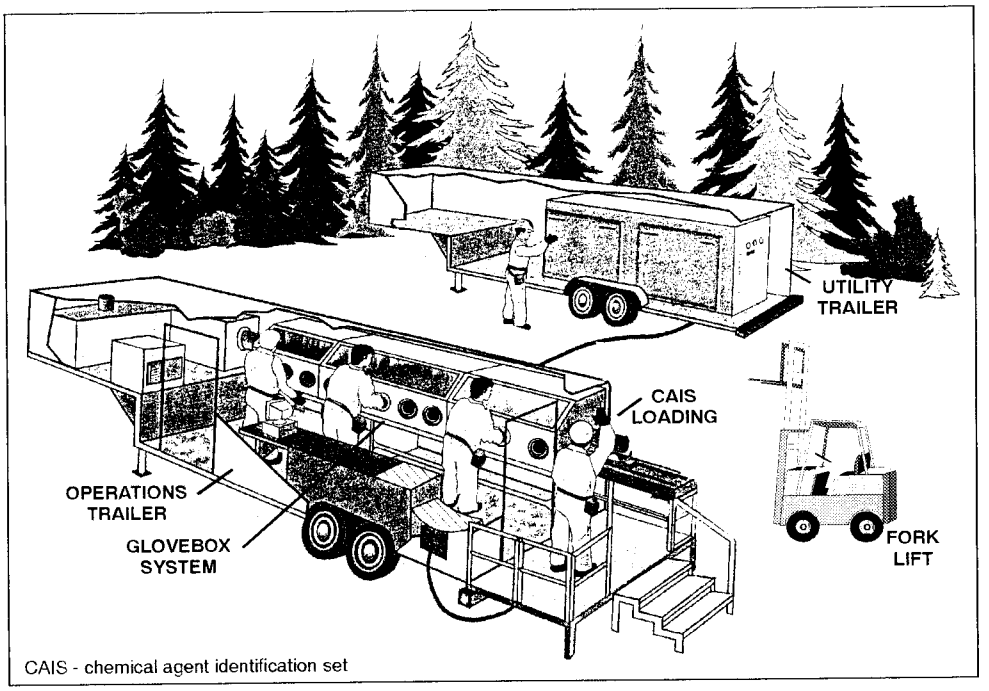


Figure C.2-2. Conceptual Drawing of the Rapid Response System

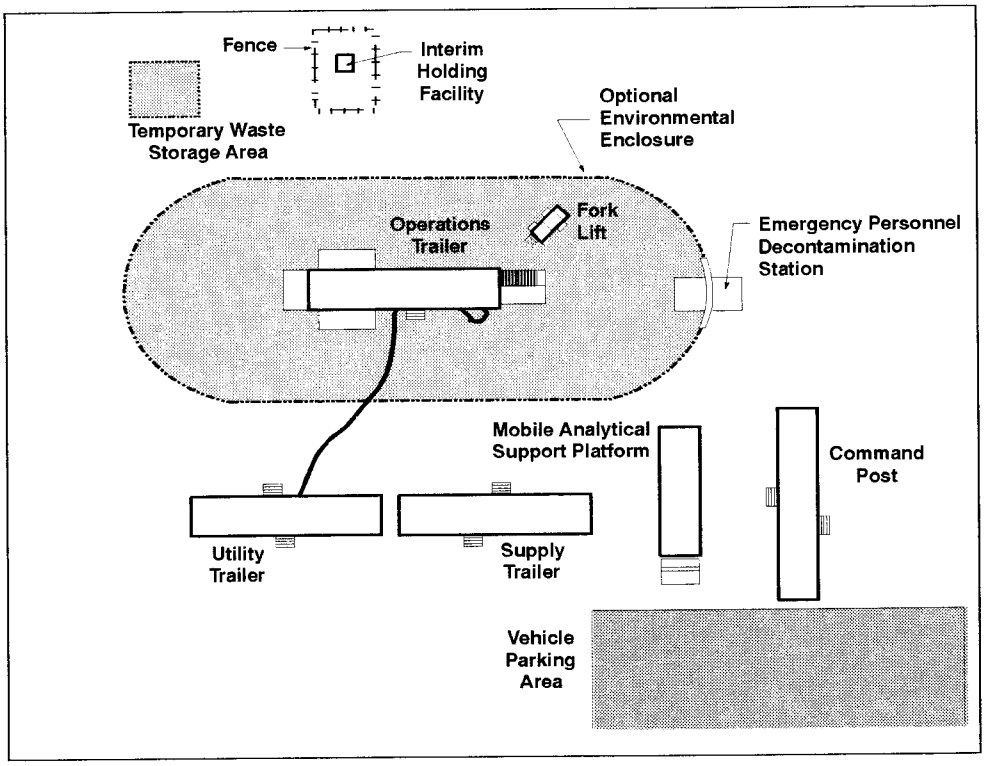


Figure C.2-3. Conceptual Site Layout of the Rapid Response System

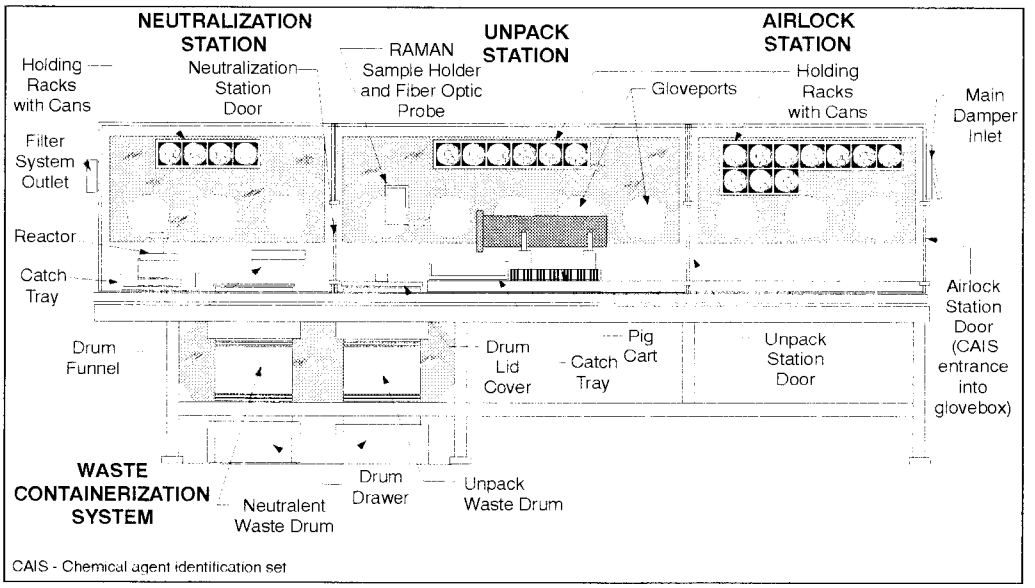


Figure C.2-4. Glovebox and Waste Containerization Systems in the Operations Trailer of the Rapid Response System (Side View)

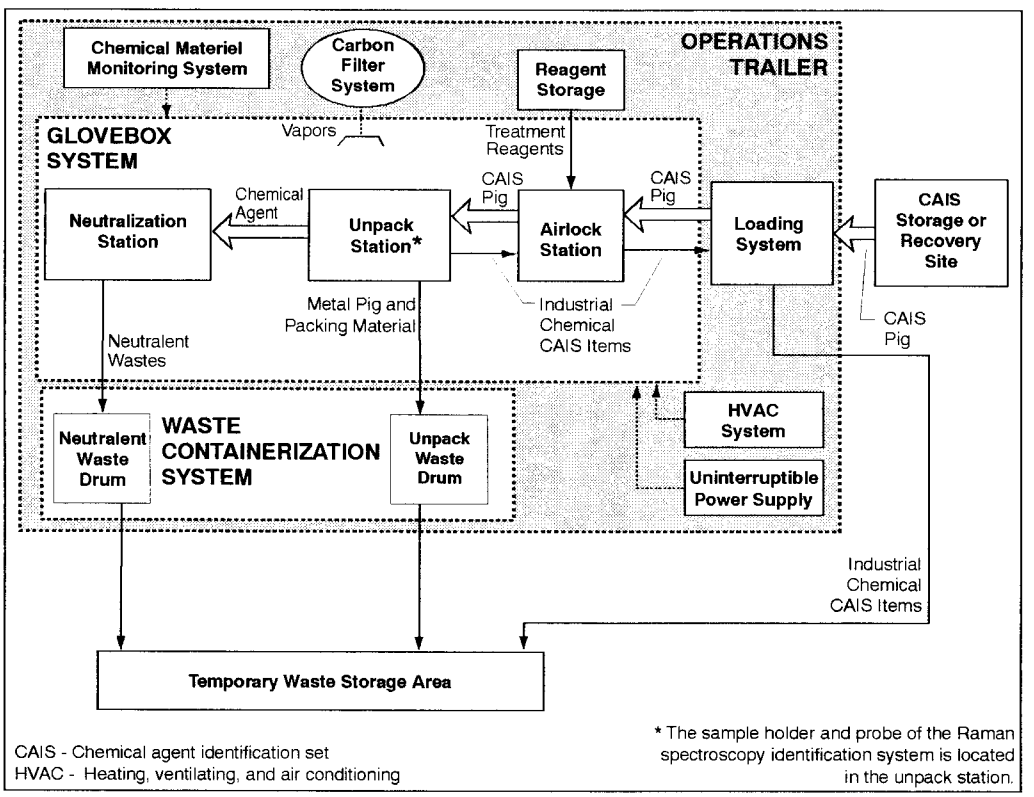


Figure C.2-5. Process Flow Diagram for the Rapid Response System

(Department of the Army, 1997a). A brief description of an environmental enclosure that could be used in conjunction with the RRS, if required, is also described.

C.2.1.1 Operations Trailer

CAIS processing and chemical agent treatment operations will be conducted within the operations trailer, which contains all of the necessary equipment, systems, and instrumentation required for operators to safely process and treat CAIS items. The external dimensions of the operations trailer will be approximately 9 feet (2.7 meters) high by 8.5 feet (2.6 meters) wide by 28 feet long (8.5 meters), with an approximate weight of 16,400 pounds (7,440 kg) without its truck or tractor. The operations trailer will include the following major components and systems:

- Loading system
- Glovebox system
- Airlock Station
- Unpack Station
- Neutralization Station
- Raman spectrophotometer identification system
- Waste containerization system
- Heating, ventilation, and air conditioning (HVAC) system
- Carbon filter system
- Uninterruptible power supply system
- Chemical materiel air monitoring system

Each of these major components and systems are discussed below, except for the chemical materiel air monitoring system, which is discussed in Section C.2.2.

Loading System. The loading system, located on the outside rear of the operations trailer, will be used to bring overpack containers of CAIS items into the trailer. The loading system will require a forklift for lifting the overpack containers of CAIS items onto a cart where the CAIS overpack container will be secured. The cart will be located on an outside track section leading into the glovebox system of the operations trailer. RRS operators will wear appropriate PPE when conducting CAIS loading operations.

Glovebox System. RRS processing operations will be conducted within the operations trailer glovebox system. The glovebox system will be composed of a single glovebox that will be divided into three coupled stations: the airlock station, the unpack station, and the neutralization station. These three stations will be maintained under negative pressure during CAIS treatment operations. Figure C.2-4 displays the layout of the RRS glovebox system.

Airlock Station. The first station of the glovebox will be an airlock, which allows the introduction of CAIS and supporting tools and equipment into the glovebox while maintaining

negative pressure in the two processing stations. The airlock will also be used to monitor tools and equipment prior to their removal from the glovebox to ensure that they are not contaminated with chemical agent or industrial chemicals. CAIS and tools will enter the operations trailer through the airlock station door by way of the loading system cart track. All doors of the glovebox will be closed and negative pressure will be restored in the airlock station before operations continue.

Unpack Station. The unpack station will be used to access containers containing CAIS ampoules and bottles, unpack CAIS components, identify and segregate CAIS components, accumulate industrial chemical CAIS components, and package CAIS packing materials (absorbent material and metal parts). CAIS ampoules and bottles will be removed from their shipping and storage container in the unpack station.

Following the removal of CAIS ampoules from their overpack container, their contents will be identified using a Raman spectrophotometer identification system and segregated by content. CAIS ampoules and bottles to be treated in the reactor vessel will be stored in the unpack station until a sufficient quantity of ampoules or bottles has accumulated and a neutralization operation can begin. Three ampoules or one bottle will be transferred to the neutralization station as required for each batch reaction.

Ampoules and bottles containing industrial chemicals will be segregated, repackaged into intermediate containers, monitored to ensure none are contaminated or leaking, and removed from the glovebox through the airlock station. Outside of the operations trailer, the intermediate containers will be appropriately packaged according to USDOT hazard class for transportation and subsequent treatment.

If a leak or spill is identified during unpacking operations and is determined to be chemical agent, the contaminated containers and packing material (such as absorbent material) will be decontaminated with either the RRS treatment reagents or a bleach solution and disposed of in the solid waste drum containerization system. Chemical agent analysis will be conducted on a representative sample from the waste to determine the effectiveness of decontamination.

Neutralization Station. The neutralization station will contain a small, one-gallon (3.8-liter) reactor vessel designed for treatment of CAIS chemical agents. A stainless-steel catch tray will be located under the reactor vessel for containment of liquid spills that may inadvertently splash or leak from the reactor vessel.

CAIS will be placed into the reactor together with an appropriate reagent. The ampoules and bottles containing chemical agent will be crushed in a closed reactor to release the chemical agent, and neutralization will be initiated. A removable handle will be attached to the crusher to allow operators to periodically stir the contents of the reactor vessel. Once the chemical agent is treated in the reactor vessel, the neutralent waste—including the crushed glass and charcoal—will be poured into the liquid waste drum located in the waste

containerization system. The content of each liquid waste drum will be sampled and analyzed to determine treatment effectiveness prior to removal from the glovebox. Samples will also be taken for RCRA characterization analysis as required, but these samples will not be released for disposal until agent destruction is confirmed.

Liquid waste drums will be removed, packaged, and labeled in accordance with RCRA and USDOT standards. The drums will be managed in accordance with appropriate RCRA standards for storage of hazardous waste prior to being transported, subsequently treated, and disposed of at a TSDF. Solid waste removed from the CAIS packaging containers will be placed in solid waste drums and will be handled in an identical fashion.

At the end of CAIS operations at a site, the glovebox system will be cleaned, decontaminated as necessary, and closed prior to demobilization. Cleanup activities will generate spent decontamination solutions, rinse waters, and spent cleanup materials which will be containerized and properly characterized for further treatment and ultimate disposal, as required.

Raman Spectrophotometer Identification System. The Raman spectroscopy system will be used to nondestructively evaluate all liquid chemical agent found in CAIS ampoules and bottles while they are in the unpack station. Laser energy emitted inside a sample holder will excite the container contents and returns shifted light back to the imaging spectrograph to produce a characteristic spectra. The spectra will be compared to spectra from known chemicals and will then be interpreted by qualified operators to identify the container contents.

Waste Containerization System

The waste containerization system will be used to accumulate metal pieces, packing materials, and neutralents generated from CAIS processing operations. This system will consist of two independent compartments: the solid waste drum, which will be located underneath the unpack station for metal pieces and packing materials; and the liquid waste drum, which will be located under the neutralization station for the liquid neutralent and treatment wastes. Each compartment will hold a 30-gallon (114-liter) waste drum. A vapor-tight seal will be created between the drum and the glovebox system once the drums are in position. Any vapors emitted from the drums will enter the glovebox system and will be vented to the carbon filter system in the operations trailer.

The drums will be accessible from outside the operations trailer by independently operated drawers; these drawers will permit the drums to be moved into and out of position under the glovebox unpack and neutralization stations. Electric actuators will be used to lift the drums into and out of position under the two glovebox stations. RRS operators will wear appropriate PPE when removing and handling waste drums from the waste containerization system.

Heating, Ventilation, and Air Conditioning (HVAC) System

The HVAC system will ensure proper operating temperatures and relative humidity for the equipment and personnel within the operations trailer. Conditioned air will also serve as the makeup air for the glovebox system.

Carbon Filter System

The carbon filter system, located at the exhaust end of the glovebox, will filter all air, gases, and vapors leaving the glovebox system. The carbon filter system will consist of a filter fan, high-efficiency particulate air (HEPA) filters, and charcoal filter elements that capture contaminants that escape from the glovebox. A coconut shell carbon absorber filter bank of two filters will preferentially adsorb chloroform, but it will also adsorb other CAIS materials. An impregnated carbon absorber ASZM-TEDA filter bank of two filters will be designed to adsorb chemical agent. In each filter bank, the second filter element will act as a safety or backup filter to the first. The carbon filter system is depicted in Figure C.2-6.

The carbon filter system will have several near–real-time monitoring locations that will be able to detect blister agents, volatile industrial chemicals, and chloroform before concentrations reach hazardous levels (Figure C.2-7). A MINICAMS® sampling point will be located between the first and second coconut shell carbon filter elements in the coconut carbon bank to detect chloroform. Another MINICAMS® sampling point will be located to detect blister agent and industrial chemical breakthrough between the first and second impregnated carbon filters.

The spent filter elements will be removed from the carbon filter system using a bag-in and bag-out procedure which will prevent vapors from the spent filter elements from escaping into the air outside of the operations trailer. Spent filter elements will be double-bagged and containerized for ultimate disposition.

Uninterruptible Power Supply System

The operations trailer will be equipped with an uninterruptible power supply system which will be able to maintain continuous, short-term power to the critical electronic systems in the operations trailer in the event of a total power failure. The uninterruptible power supply system will permit power source switching of critical systems and orderly shutdown of electronic equipment and will prevent loss of electronically stored data during the approximately 30-second period that will be required to bring the emergency generator on line.

C.2.1.2 Utility Trailer

The utility trailer will contain two diesel-powered generators—one for providing primary electrical power and the second to serve as backup. Although the use of host facility power will be preferred, the primary generator will be able to power all RRS equipment. The backup generator will automatically come on line within 30 seconds of loss of primary power

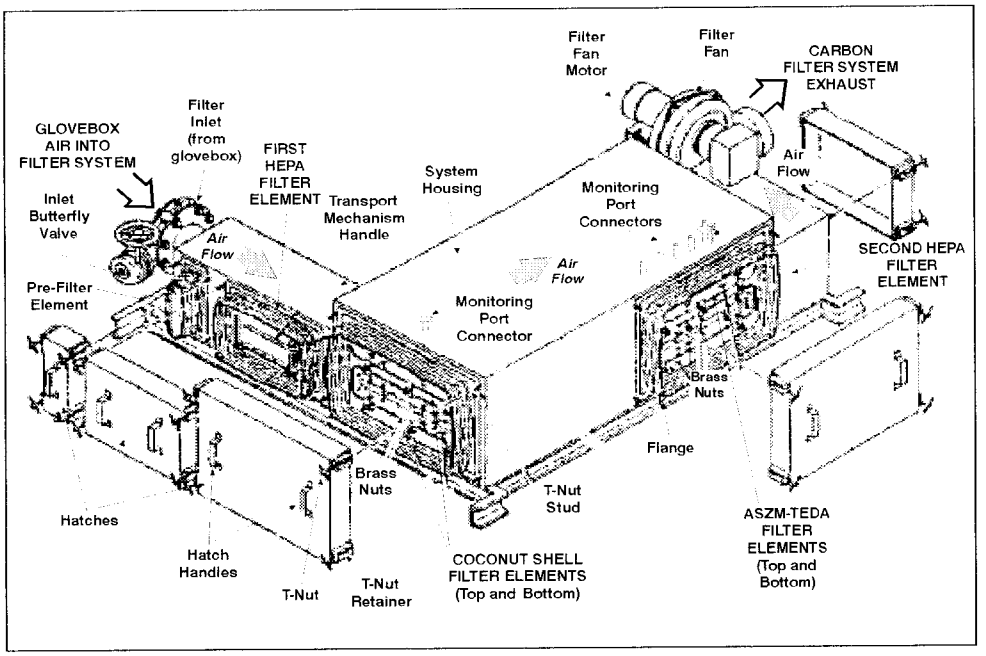


Figure C.2-6. Diagram of the Carbon Filter System in the Glovebox System of the Rapid Response System

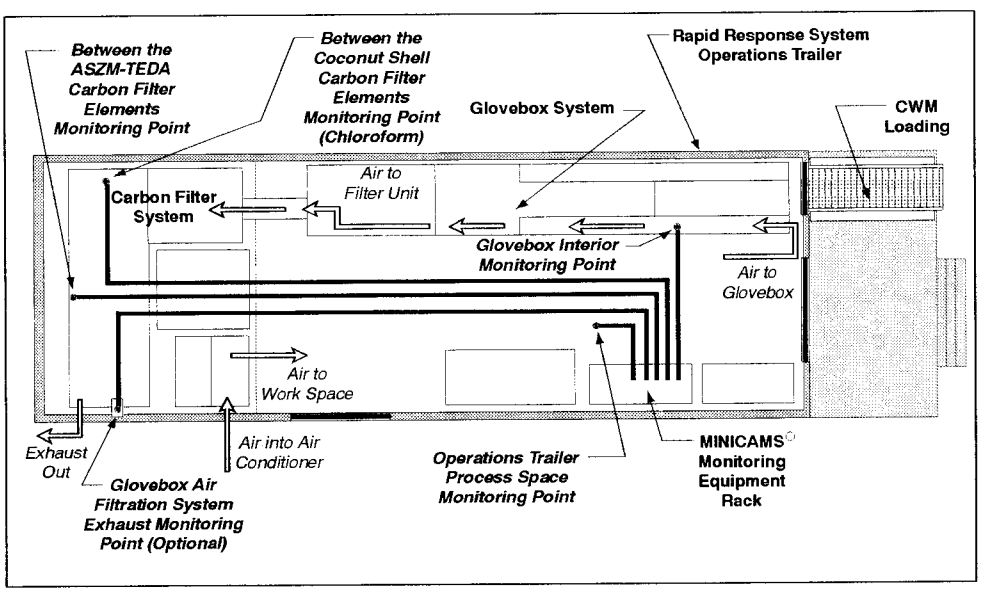


Figure C.2-7. MINICAMS® Sample Line Locations and Air Flow for the Rapid Response System

and will be capable of powering selected operations trailer systems. The external dimensions of the utility trailer will be approximately 9 feet (2.7 meters) high by 8.5 feet (2.6 meters) wide by 28 feet (8.5 meters) long, with an approximate weight of 15,280 pounds (6,930 kg) without its truck or tractor attached.

C.2.1.3 Environmental Enclosure

Although the RRS will be designed to operate in the open, RRS operations could be conducted in an existing and appropriate building or in an environmental enclosure to provide an additional level of vapor containment between the operations trailer and the ambient environment, as well as protection from the ambient environment.

The environmental enclosure will include flexible walls over a rigid framework with a portable ground cover liner. Interlocking pierced steel planking will be placed in the structure for concentrated load areas, and an expanded metal mat floor surface will be placed where forklifts or other vehicles travel inside the enclosure. The enclosure will have an HVAC system to provide heating, cooling, and humidity control, as well as a charcoal-type filtration system to filter the air passing out of the environmental enclosure. Panels built into the walls of the enclosure will allow for penetration of electrical and other support service lines. An airlock will provide for entrance and egress of personnel, and sufficient space will be provided for personnel to shower and change into and out of PPE. A second airlock will be used to accommodate the movement of vehicles and equipment into and out of the enclosure.

C.2.2 Monitoring Systems

The RRS monitoring system will ensure the safety of the workers, the general public, and the environment. The monitoring system will have two types of air monitors: (1) near–real-time MINICAMS® monitors and (2) confirmation and historical depot area air monitoring system (DAAMS) monitors. Records from both types of monitors will be retained to document whether detectable hazardous constituents were or were not released to the atmosphere by RRS operations.

DAAMS equipment and colorimetric tubes will be used for confirmation and historical monitoring purposes. DAAMS monitors will be used for chemical agent detection, and colorimetric tubes will be used for industrial chemical detection.

The following subsection describe the near–real-time and confirmation and historical monitoring systems that will be used with the RRS, as described in the site monitoring plan for the RRS test (Department of the Army, 1996b) and the monitoring concept plan for buried CWM (Department of the Army, 1997f).

C.2.2.1 Near–Real-Time Air Monitoring System

The near–real-time MINICAMS® monitoring system will use gas chromatography to detect airborne concentrations of agents (HD, HN, and Lewisite), and industrial chemicals (chloroform, phosgene, cyanogen chloride, and chloropicrin) that may be above workplace

exposure limits. A MINICAMS® is an automated gas chromatograph that operates by alternating between sampling and analysis cycles. During the sample cycle, a vacuum pump pulls an air sample into the MINICAMS® through a solid sorbent tube or into a sample loop where the analytes are collected. Heated sample transfer lines ensure that chemical materiel being transported down the sample line does not condense or become adsorbed onto walls of the sample line (Department of the Army, 1996b). Figure C.2-7 illustrates a MINICAMS® sample station.

When the concentration of the chemical agent detected is at or above the alarm set point, then the MINICAMS® alarm will activate. The combined sample time and analysis times will vary from 3 to 10 minutes depending on the MINICAMS® configuration. A stream selection system will accompany each of the five MINICAMS® which will be used to support RRS operations and it will allow each MINICAMS® to collect samples from different sampling ports as appropriate. Each of the five MINICAMS® will have a different configuration, allowing simultaneous monitoring of all eight CAIS chemicals.

When detecting, the MINICAMS® will automatically send a concentration report to the printer/floppy disk drive which will include the date, time, instrument number, sampling port number, chemical materiel identity, summary, MINICAMS® operational mode, and the chromatographic information. At the end of each RRS operational day, the concentration report will be collected from the printer and will be filed in the RRS air monitoring files (Department of the Army, 1996b).

The five MINICAMS® units will cycle between different RRS sample collection points. The sample collection points will be: (1) between the ASZM-TEDA carbon filter elements; (2) between the coconut shell carbon filter elements; (3) inside the RRS operations trailer work space; (4) in the interior of the RRS glovebox (when required); and, (5) in the carbon filter exhaust port as required. Automatic monitoring at the sampling collection points inside of the RRS operations trailer work space will be required to be online before any chemical materiel operations commence in the RRS glovebox, and will be required to stay online until treatment operations conclude and the glovebox has been successfully decontaminated (Department of the Army, 1996b). Figure C.2-7 shows the locations of the sample lines and airflow for the RRS. Figure C.2-6 shows the carbon filter system.

The area between the ASZM-TEDA carbon filter elements and the operations trailer workspace will be sampled alternately with the MINICAMS® for HD, HN, Lewisite, phosgene, cyanogen chloride, and chloropicrin. The area between the coconut shell carbon filter elements and the operations trailer workspace will be sampled alternately with the MINICAMS® configured to detect chloroform. The glovebox interior and the carbon filter system exhaust will be sampled with MINICAMS® on an as-needed basis (Department of the Army, 1996b).

C.2.2.2 Historical and Confirmation Monitoring

Depot Area Air Monitoring System. Should one of the MINICAMS® detect agent at the area between the ASZM-TEDA carbon filter elements, between the coconut shell carbon filter elements, or inside the RRS operations trailer workspace, the presence of agent will be confirmed by the collections of air samples using depot area air monitoring system (DAAMS) stations. The air samples will be analyzed for HD, HN, and Lewisite. In addition to providing confirmation of alarms, the DAAMS will be used at these stations and a separate station for the exhaust from the carbon filter system to collect historical samples. All MINICAM® alarms will be considered positive alarms, and appropriate action will be taken based on the alarms (Department of the Army, 1996b).

A DAAMS consists of a vacuum pump, a sequencer, and sample tubes. The vacuum pump continuously draws air through glass tubes packed with a solid sorbent material to trap airborne HD, HN, and Lewisite. Each DAAMS station will be three sets of tubes, and the station sequencer will allow the sample sets to be collected in rotation for uninterrupted monitoring. A sample set will comprise of one DAAMS tube for HD, one tube for HN, and one tube for Lewisite. Following the collection of the DAAMS samples, they will be analyzed using a gas chromatograph located in the MASP (Department of the Army, 1996b).

DAAMS historical monitoring will be operated continuously until the conclusion of RRS operations. Analysis of DAAMS tubes to confirm a near–real-time alarm will be undertaken as soon as possible.

Colorimetric Tube Monitoring. Colorimetric tubes will be used to confirm the presence of phosgene, cyanogen chloride, chloropicrin, and chloroform vapors in the event of a near–real-time monitor alarm. A colorimetric tube sampling system will consist of a sample tube and a pump. The pump will be used to draw a known volume of air into a tube. Each colorimetric tube will be designated for a specific industrial chemical; the tube will contain a chemical sorbent which will change color when exposed to the specific chemical or class of chemicals. The length of the color change within the tube equates to a concentration of the specific chemical in the air. The colorimetric tubes will not be placed in a sample station like the continuous monitors, but they will be used to sample air in the same location as the MINICAMS®. The filter housings and exhaust port will have access ports to allow insertion of the colorimetric tube into the same airstream as that being monitored by the MINICAMS® (Department of the Army, 1996b).

C.2.3 Treatment Chemistry

The RRS treatment of chemical agents contained in CAIS items will be based on chemical neutralization processes designed to convert chemical agents into chemical wastes that could be released from Army control and, similar to the industrial chemicals, be transported to a TSDF for final treatment. To identify the appropriate chemical treatment reagents for CAIS items containing chemical agent, the Army's Chemical and Biological

Center evaluated different chemicals. In this evaluation, several criteria were considered, including the following (Department of the Army, 1997b; Department of the Army, 1997c; Department of the Army, 1997d):

- Reaction will be rapid and complete.
- Ratio of treatment reagent to chemical agent will be manageable.
- Reaction will generate minimal heat and pressure.
- Components of the reagent mixture will be commercially available and cost-effective.
- Treatment reagents will be simple to prepare.
- Treatment reagent components will have a long shelf life.
- Treatment reagents and reactions could be managed safely.
- Organic solvents will be used to achieve better solubility and to better displace blister agents from the small pores present in granulated charcoal.

As a result of the evaluation, 1,3-dichloro-5,5-dimethylhydantoin (DCDMH) was selected as the primary component of the treatment reagents to be used. In addition to its potential for breaking the molecular bonds of the chemical agents contained in CAIS items, DCDMH was also selected because of its relatively low reactivity with chloroform, which is present in some of the CAIS items. DCDMH has been widely used as a chlorinating agent in the treatment or purification of water, such as in swimming pools. DCDMH and other components of the treatment reagents are listed in Table C.2-1. To simplify operator identification of the appropriate treatment reagent for the different CAIS items to be treated, each of the treatment reagents will be color-coded.

Laboratory studies indicate that the reactions of the treatment reagents with the chemical agents in liquids are fast, with half-lives on the order of 30 seconds or less (Department of the Army, 1997b; Department of the Army, 1997c; Department of the Army, 1997d). Residual agent concentrations in neutralent solutions were reduced to less than 50 parts per million, which was the limit of detection for the initial laboratory analyses. Reactions of HD and HN on charcoal generally required 1 hour and 24 hours, respectively, to allow for adsorption of agent in the micropores of the charcoal (Department of the Army, 1997b; Department of the Army, 1997c; Department of the Army, 1997d). During the chemical reactions involving the different processes, minimal heat and pressures were generated. Table C.2-2 lists the temperatures of the reactions as measured at the surface of a reactor vessel and the pressure as measured in a reactor vessel.

Excess DCDMH will be used in the process as an inherent safety factor to prevent the presence of unacceptably high concentrations of residual chemical agent in the waste. DCDMH will be a component of the post-reaction neutralent. Reaction products from the neutralization of HD, HN, and Lewisite will include chlorinated sulfoxides and chlorinated sulfones, bis-(2-chloroethyl) amine, and chlorovinylarsonic acid. Other reaction products will

Table C.2-1. Rapid Response System Treatment Reagents

Process	Use	Reagents
Red	Nitrogen mustard (HN-1 only) Sulfur mustard (H/HD) Lewisite (L) in chloroform solution	Dichlorodimethylhydantoin (DCDMH) 0.555 molar in a mixture of: chloroform (48.5 percent) t-butyl alcohol (48.5 percent) water (3 percent)
Blue	Sulfur mustard (H/HD)	Dichlorodimethylhydantoin (DCDMH) 0.555 molar in a mixture of: chloroform (48.5 percent) t-butyl alcohol (48.5 percent) water (3 percent)
Charcoal	Nitrogen mustard or sulfur mustard absorbed on charcoal	Dichlorodimethylhydantoin (DCDMH) in chloroform
Charcoal–L	Lewisite absorbed on charcoal	Dichlorodimethylhydantoin (DCDMH) 0.555 molar in a mixture of: chloroform (48.5 percent) t-butyl alcohol (48.5 percent) water (3 percent)

Table C.2-2. Reaction Parameters for Rapid Response System Chemistry Processes

	Reaction Parameter			
	Peak Temperature		Peak Pressure	
Process	C°	F°	kilopascals	pounds/sq. inch
Blue	59	138.2	69	10
Red	28.5	83.3	35	5
Charcoal	29.5/32.6[a]	85.1/90.7[a]	17.3	2.5
Charcoal L	33.5	92.3	17.9	2.6

[a] First reported temperature is for sulfur mustard; second temperature is for nitrogen mustard.

Source: Department of the Army, 1997b, 1997c, and 1997d.

include a variety of chlorinated ethanes, butanes, and aldehydes. The constituents in the neutralents for each of the processes are listed in Table C.2-3. The neutralent products will also contain crushed glass from the CAIS glass ampoules and bottles and plastic from bottle caps.

To determine the appropriate USDOT shipping and packaging classifications of the neutralents, dermal toxicity tests and dermal irritation studies were conducted in accordance with Organization for Economic Cooperation and Development guidelines to ascertain the systemic and skin-injurant potential of neutralized CAIS waste streams (Olajos et al., 1996). The evaluations were conducted to determine whether the characteristics of the neutralents were suitable for designation in accordance with USDOT hazardous materials regulations as Packing Group I (materials that presents "great danger"), Class 6 (poisonous) materials that will be applicable to CAIS items containing chemical agent or as Packing Group III (materials that presents "minor danger"), Class 8 (corrosive) materials that will be applicable to the treatment reagents. Both short-term acute dermal toxicity tests specific for Class 6 materials and dermal irritation studies specific for Class 8 materials were conducted on the neutralents resulting from the treatment processes and the treatment reagents used in the treatment processes. Results of the studies indicated that: (1) the neutralents induced acute dermal injuries that were either comparable or lower than those produced by the treatment reagents to be used in the treatment processes, and (2) the treatment process neutralents could be transported in accordance with the less-restrictive Packing Group III hazardous materials requirements applicable to the treatment reagents rather than the Packing Group I requirements that are applicable to raw CAIS items (Olajos et al., 1996; Department of the Army, 1997e).

C.2.4 Wastes and Emissions

This section discusses the expected wastes and air emissions that may be generated from RRS processing and treatment operations, based on the RCRA permit application for the RRS system tests (Department of the Army, 1996a) and the notice of intent application for the RRS system tests (Department of the Army, 1996b). During normal operation of the RRS, no liquid effluents will be generated for discharge to surface water or groundwater, except for operational personnel sanitary waste for which either existing sanitary systems or portable facilities will be used (Department of the Army, 1996b).

C.2.4.1 Wastes

Table C.2-4 lists potential wastes, the activity or process that will generate each waste, and the physical state of each waste that will be generated from RRS unpacking and treatment operations.

Wastes generated from the treatment and decontamination of CAIS chemical agents—such as neutralents, spent decontamination solutions, and decontaminated packing materials—

Table C.2-3. Composition of Neutralent Wastes from the Rapid Response System[a]

Waste Component	Treatment Process		
	Blue (percent by weight)	Red (percent by weight)	Charcoal or Charcoal-L (percent by weight)
Chloroform	54.5–55.5	60–61	50–84
T-butyl alcohol	26–27	17–20	0–24
Water	2.2–2.4	1.7–1.9	0–1
Dichlorodimethylhydantoin (unreacted)(DCDMH)		0–4.6	0–7
Chlorodimethylhydantoin (CDMH)	2.1–5.9	1.9–5.6	2–6
5,5-dimethylhydantoin (DMH)	1–3	0–4.6	0–3
Chlorinated sulfoxides (diethyl and ethylvinyl)	5.4–7.6	0.6–2.1	0–0.4
Chlorobutanes and chlorobutenes	2.4–3.4	1.2–4.6	0–4
Chlorinated sulfones (diethyl and ethylvinyl)	0–0.1	0–0.06	0–0.3
1,1,2-trichloroethane	0–0.015	0–0.23	0–0.025
Tetrachloroethane[b]	0–0.025	0–0.2	0–0.022
Bis-(2-chloroethyl)amine		0–1	0–0.5
Chlorovinylarsonic acid		0–2.6	0–3
Acetaldehyde and chloroacetaldehyde		0–0.5	
Polychlorinated diethyl sulfides and polychlorinated ethylvinyl sulfide			0–2
Dichloroethane[c]			0–0.03
Pentachloroethane			0–0.03
Hexachloroethane[c]			0–0.01
Chloral hydrate			0–0.7
Glass/plastic	2–3	7.5–10	5–8
Charcoal			5–5.2
Additional RCRA TCLP Constituents			
Organics: Carbon tetrachloride; 1,1-dichloroethylene; tetrachloroethylene; trichloroethylene; vinyl chloride	Expected to be present in waste. Data on concentrations not yet available.		
Metals: Arsenic, barium, cadmium, chromium, lead, mercury, nickel[d], selenium, silver	Toxic characteristic metals have been assumed to be impurities in chemical agents. All metals may not be present in all wastes. Lewisite contains arsenic. Data on concentrations not yet available.		

[a] RCRA characterization of the neutralent waste stream will be completed using analytical data obtained from bench-scale demonstrations conducted at the Edgewood Chemical and Biological Center (ECBC), Aberdeen Proving Ground, MD.
[b] May be either isomer, 1,1,1,2-tetrachlorethane or 1,1,2,2-tetrachlorethane.
[c] RCRA TCLP constituents.
[d] Not a TCLP constituent. Included because it is listed in Appendix VIII – Hazardous Constituents in 40 CFR 261.

TCLP – Toxic characteristic leaching procedure (40 CFR 261.24).

Table C.2-4. Waste Streams for the Rapid Response System Treatment Site

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Neutralents	Chemical treatment (oxidation) of chemical agent in chemical agent identification set items	Liquid[b]	Permitted commercial hazardous waste treatment, storage, and disposal facility (TSDF).
Repackaged industrial chemicals	Repackaging of industrial chemical CAIS components in appropriate shipping containers	Varies[c] (solid/liquid)	Permitted hazardous waste TSDF.
Decontaminated metal containers and packing materials	Decontamination of metal containers and packing materials contaminated by agent	Solid (may contain free liquids)	Permitted hazardous waste TSDF.
Non-agent contaminated metal containers and packing materials	Unpacking of CAIS items containing industrial chemicals (spill or leak identified)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Uncontaminated metal containers and packing materials	Unpacking of CAIS items (no spill or leak identified)	Solid	Permitted commercial hazardous waste TSDF; permitted solid waste landfill.
Spent decontamination solutions and rinse waters	Decontamination, cleaning, and rinsing operations (including emergency personnel decontamination station)	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent filter elements from carbon filter system	Change-out and replacement of filter elements from carbon filter system	Solid	Permitted commercial hazardous waste TSDF.

Table C.2-4 (Continued)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Other spent filter elements	Change-out and replacement of filter elements other than those from carbon filter system	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Used personal protective equipment	Disposable gloves and other PPE generated from waste handling operations (for example, waste drum change-out, filter change-out)	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Laboratory wastes	Laboratory activities (for example, analysis, calibration, maintenance, and cleaning); spent chemicals and materials	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.
Spent cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
HVAC condensate	Use of HVAC systems	Liquid	Tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in containers for subsequent treatment at an existing wastewater treatment facility.
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.

Table C.2-4 (Concluded)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Includes wastes from the pre-operational survey.
[b] The neutralent wastes would contain pieces of broken glass. The neutralent waste generated from the treatment of CAIS items containing chemical agent adsorbed onto charcoal would also contain charcoal granules.
[c] The physical state would vary depending on the industrial chemical CAIS items present.
[d] Wastes would be tested for the presence of chemical agent. If present, the waste would be decontaminated and sent to a RCRA hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

HVAC—Heating, ventilating, and air conditioning
TSDF—Treatment, storage and disposal facility

may be RCRA-characteristic hazardous waste as specified in RCRA regulations (40 CFR part 261). Potential constituents include the toxicity characteristic metals—arsenic (D004), barium (D005), cadmium (D006), chromium (D007), lead (D008), mercury (D009), selenium (D010), and silver (D011)—and various toxicity characteristic organics, such as chloroform (D022); 1,2-dichloroethane (D028), hexachloroethane (D034), tetrachloroethylene (D039), trichloroethylene (D040), and vinyl chloride (D043) (Department of the Army, 1996b). Historically, toxicity characteristic metals have been found to be impurities in chemical agents, and certain toxicity characteristic organic constituents have been identified as impurities or degradation products of mustard agents.

The neutralent waste from RRS treatment may exhibit the RCRA characteristic of corrosivity (D002). Waste characterization and analysis will be conducted after generation to determine if the neutralents exhibit this characteristic. Actual waste characterization analysis, or generator knowledge gained from sampling and analysis of the waste streams generated during the system tests of the RRS will be used to characterize the wastes generated from RRS treatment operations. In addition, some states define wastes generated from chemical agent demilitarization operations as a state-listed hazardous waste, and such wastes will be managed accordingly within those states.

Phosgene and cyanogen chloride are RCRA-listed hazardous wastes (P095 and P033, respectively) (40 CFR 261.33). Repacks of these industrial chemicals and cleanup or packing materials contaminated with such industrial chemicals will be characterized with the appropriate waste code.

In addition to the process and treatment wastes, waste may also be generated from RRS maintenance activities, such as used lubricants, fuel filters, and oil-contaminated rags. Such maintenance wastes will be appropriately characterized, containerized, and stored pending ultimate disposition.

Based on unpacking, identifying, and segregating items in one CAIS pig per day, it is estimated that approximately one 30-gallon (114-liter) drum of dunnage and packing materials will be generated per day. Once treatment operations are initiated, it is estimated that less than 1 gallon (3.8 liters) of neutralent waste will be generated for every three 40-milliliter CAIS ampoules or one 110-milliliter CAIS bottle. It is estimated that no more than 15 gallons (56.8 liters) of neutralent will be generated per day, assuming treatment of 12 to 15 CAIS ampoules or bottles.

C.2.4.2 Emissions

The RRS operations trailer will be designed to conduct CAIS unpacking and treatment operations under engineering controls. The near–real-time monitoring equipment coupled with the redundant filter elements will respectively detect and control the CAIS chemical agents and industrial chemicals before their release into the environment. Although current planning and evaluations do not indicate a need for further protective measures from

potential emissions, RRS operations could be conducted in an appropriate existing building or in an environmental enclosure to provide further containment and filtration of possible emissions from the operations trailer.

The two diesel-powered generators in the utility trailer will be the sole source of air emissions from the utility trailer. The rated power is 65 kilowatts for the main generator and 15 kilowatts for the backup generator. Periodic maintenance of the two diesel-powered generators will be performed to sustain efficient operation.

C.2.5 Required Resources

About 65 kilowatts will be required to operate the RRS. The RRS could be operated independently of local electrical power supply systems by the use of the diesel-powered generators.

Water will be required for personnel decontamination and system closure operations. A drinking water supply and lavatory facilities will be required for RRS and site personnel. It is estimated that a maximum of 1,500 gallons (5,680 liters) of water per day will be required. Existing water supply systems and sanitary facilities will be used when available, and transportable systems will have to be supplied when these utilities are not available.

The assembly and use of the RRS will require less than 1 acre (0.4 hectares) of land on a level surface. Approximately 17 personnel will be required for RRS operations, including engineers, scientists, and certified operators. The operational crew is expected to include the following:

- RRS manager (chemical or environmental engineer)
- Site safety officer (environmental compliance and safety professional)
- Logistics manager (maintenance and supply experience)
- Office manager (administrative and logistics background in a field environment)
- Raman operator (chemical engineer or certified operator with Raman expertise)
- Laboratory operators (chemist and laboratory technicians certified on MINICAMS®)
- Monitoring specialists (certified MINICAMS® operators)
- Chemical technicians (glovebox operators, personnel decontamination station operators, waste handlers)

Engineers and technicians from the U.S. Army Ammunition Equipment Directorate and the Edgewood Chemical and Biological Center will be available to assist the RRS crew, if required.

C.3 Munitions Management Device—Version One

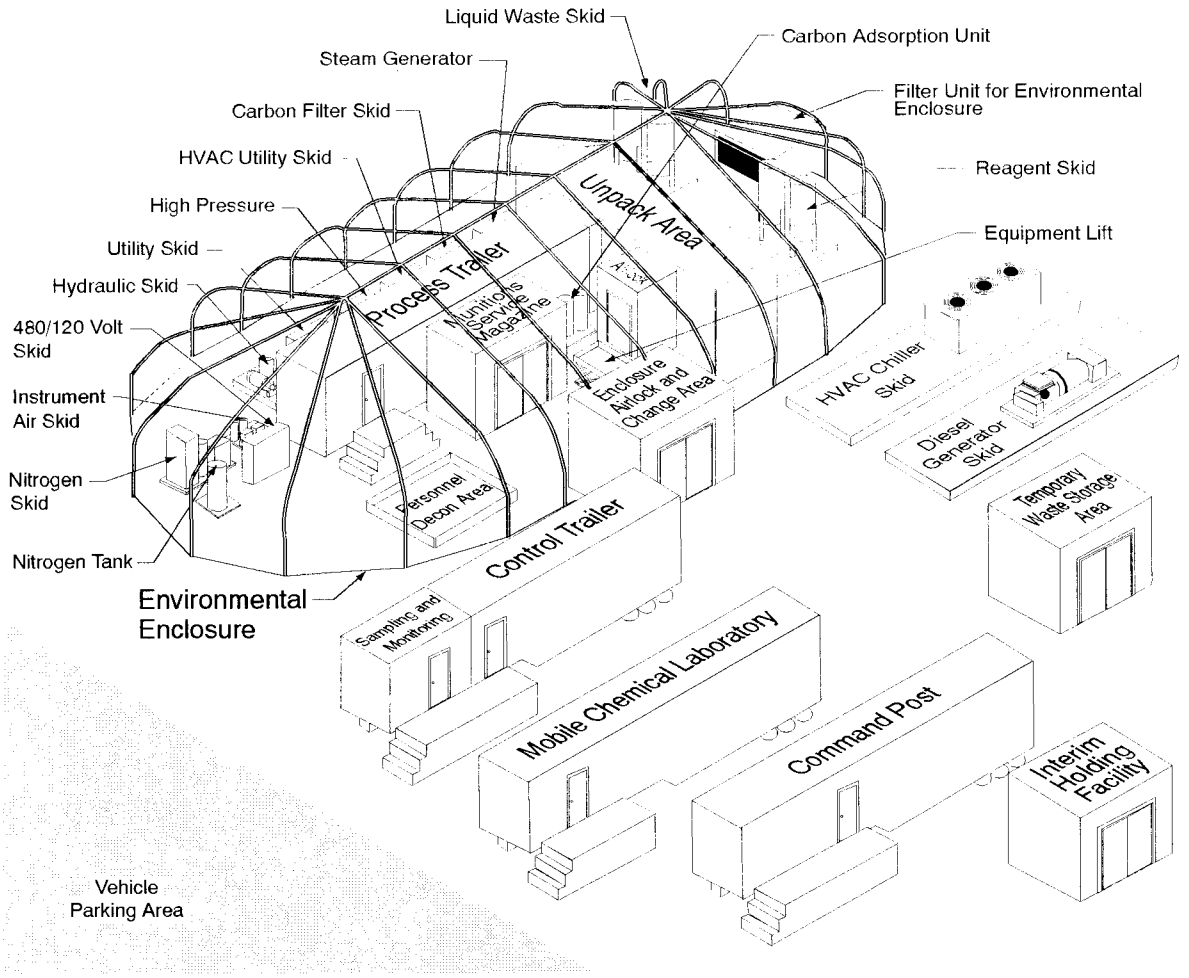
The Munitions Management Device—Version One (MMD-1) is a transportable chemical treatment system that is being developed to safely treat non-explosively configured non-stockpile chemical munitions and small containers of chemical agent that have a maximum diameter not exceeding 8 inches (20 centimeters). Non-explosively configured munitions—munitions that have no fuzes, bursters, or propellants—include a variety of projectiles (for example, 75-, 105-, and 155-millimeter, and 8-inch projectiles), mortars, bombs up to about 500 pounds (222 kilograms) gross weight, and bomblets. Appendix B contains figures of some of these different types of munitions. The MMD-1 will also be able to treat a variety of chemical agent shipping or storage containers, including USDOT bottles.

As part of the development of the MMD-1, chemical agents fills—sulfur mustard (HD), the nerve agents sarin (GB) and VX, and the industrial chemical phosgene—that represent fills likely to be encountered in recovered non-stockpile CWM have been identified for testing in the prototype MMD-1 system. After completion of the testing of the prototype MMD-1 system, the Army will evaluate a capability for treating additional chemical agents and industrial chemicals. Munitions containing industrial chemicals that will not be treated in the MMD-1 will be repackaged according to military and USDOT specifications for shipment to an approved treatment, storage, and disposal facility (TSDF) for subsequent treatment and disposal. It is expected that the majority of the recovered munitions and containers treated in the MMD-1 will contain HD.

The MMD-1 system consists of a transportable unpack area, a process trailer, a control trailer, and several skid-mounted process and utility systems. The accessing and treatment of non-stockpile CWM will occur in a sealed vessel within the process trailer, and the process will be controlled and monitored from the control trailer. The MMD-1 system was designed for transportation by ground (either road or rail) and by water (either ship or barge).

Those components of the MMD-1 system that can potentially contact chemical warfare agent or other toxic chemical materiel will be located in an appropriate building or, if an appropriate building is not available, in an environmental enclosure. The building or environmental enclosure will provide an additional measure of chemical vapor containment, climate control, and protection. The building or enclosure will be equipped with its own air filtration system, chemical agent air monitoring equipment, and internal lighting. A mobile chemical laboratory will accompany the MMD-1 to provide the necessary analytical support for determining treatment effectiveness and for analyzing air monitoring samples.

Other support facilities as shown in Figure C.3-1—a conceptual site layout for the MMD-1—could accompany the MMD-1 trailers and the mobile chemical laboratory if such facilities are not available at a site. These other support facilities could include an interim holding facility (IHF) for storage of non-stockpile CWM and a command post for



HVAC - Heating, ventilation, and air conditioning

Figure C.3-1. Conceptual Site Layout of the Munitions Management Device - Version One

administrative personnel. Both a temporary waste storage area and a parking area will also need to be established if such facilities are not available.

The following subsections of this appendix describe treatment operations (Section C.3.1), the major MMD-1 components and systems (Section C.3.2), process chemistry (Section C.3.3) the wastes and emissions that will be generated during MMD-1 operations (Section C.3.4), monitoring systems (Section C.3.5), the resources required during operation (Section C.3.6), and the regulatory design and operating features incorporated into the system (Section C.3.7).

C.3.1 Treatment Operations

MMD-1 operations will begin when personnel wearing suitable protective garments transfer an overpacked, non-explosively configured non-stockpile CWM item from a holding or storage facility to the unpack area. In the unpack area, the interior of the overpack will be monitored to check for leakage from the CWM item. If the CWM is not leaking, it will be removed from the overpack, and clamped onto a holding fixture. The fixture with the CWM will then be placed onto a cart to be transported to the process trailer. If a CWM item is leaking, an attempt will be made to patch the item so that it can be processed. If it is not possible to patch the item, it will be repacked and returned to storage to await special treatment.

At the process trailer, the CWM item will be manually placed on a carriage that carries the munition into a munition treatment vessel (MTV) in the process trailer. Once the munition is inside the MTV, the MTV will be sealed and pressurized with nitrogen. The personnel will then leave the area, and from this point on, the system will be operated remotely until the munition and treatment system is decontaminated. An operator inside the control room will remotely position the munition carriage so that the munition is located at a predetermined position under a cutting tool inside the MTV. Once the munition is positioned, a hole will be cut in the CWM item to allow vapor to escape into the sealed treatment vessel. A vapor sample will then be drawn into an analyzer to verify whether the chemical fill inside the item is the same as was earlier determined using nondestructive techniques such as portable isotopic neutron spectroscopy. At this point, the appropriate chemical reagent solution for the identified chemical will be prepared and placed in the reagent storage tank (see Section C.3.3 for a description of the reagent solutions that will be used for the different CWM chemicals and for the associated reaction chemistry). For some CWM chemicals, it will be necessary to heat the prepared reagent solution before use. When treating liquid CWM chemicals, the bottom of the MTV will be filled with a measured volume of reagent. The munition will then be rotated so that its contents drain into the MTV and mix with the reagent. The mixture will then be recirculated in the MTV using a recirculation pump. Process gases and gaseous industrial chemicals—e.g. phosgene—will be processed by pumping the gases through a sparger into reagent in the liquid reactor vessel (LRV) and by spraying reagent into the MTV to react with any residual gas.

After a predetermined period of time, the liquids in the MTV will be pumped to the LRV and either be retained for reuse or transferred to an interim holding tank. The contents of the LRV will initially be used to decontaminate the munition carcass or other container and the MTV using a pressure wash system. Prior to reuse or transfer, a sample of the reactant mixture (neutralent) in the LRV will be taken and analyzed for chemical warfare agent concentration. When the chemical warfare agent concentration is at or below the permitted level, the neutralent will be transferred to waste storage tanks pending shipment to a permitted hazardous waste TSDF. If necessary, fresh reagent will be transferred to the LRV to reduce the concentration of chemical agent or industrial chemical to at or below the permitted level before reuse or disposal. After the munition or container and the MTV are decontaminated, an air sample will be taken from the interior of the MTV and analyzed for chemical warfare agent concentration. If the concentration is below the permitted level, the MTV will be manually opened and the munition or container carcass and holding fixture will be removed and transferred back to the unpack area for further treatment. Residual solid wastes in the MTV will also be removed and appropriately containerized, characterized, and temporarily stored pending ultimate disposition.

In the unpack area, the munition or container carcass will be cut into sections and bagged. The munitions container will ultimately be blasted with an abrasive inside a glovebox to remove surface paint and corrosion. The cleaned carcass will be packaged for transfer to an Army smelter for recycling or sent to a permitted TSDF for disposal. All solid residues—e.g., blasting media, rags, and saw blades—will be placed in containers meeting USDOT specifications, appropriately labeled, and held pending ultimate disposition. Figure C.3-2 presents a process flow diagram of the MMD-1 processing and treatment operations described above.

C.3.2 Components of the Munitions Management Device—Version One

The subsections that follow describe the various components and subsystems of the MMD-1 based on system descriptions of the MMD-1 prototype (Department of the Army, 1996c; Department of the Army, 1997n; Department of the Army, 1997o) and the RCRA permit application for the MMD-1 prototype system test (Department of the Army, 1997m). The major components and systems include (1) the unpack area, (2) the process trailer, (3) the control trailer, (4) the utility and support systems, and (5) an environmental enclosure or an existing building or structure that will contain any components of the MMD-1 system that have the potential for chemical materiel contamination. Monitoring systems, which are a major component of the MMD-1 and integral to its operation, are described separately in Section C.3.5.

The NSCMP is considering the potential use of bulk item accessing equipment, which is being designed for the MMD-2, with the MMD-1 as well. A description of the bulk item accessing equipment is included in the description of the MMD-2 in Section C.4.

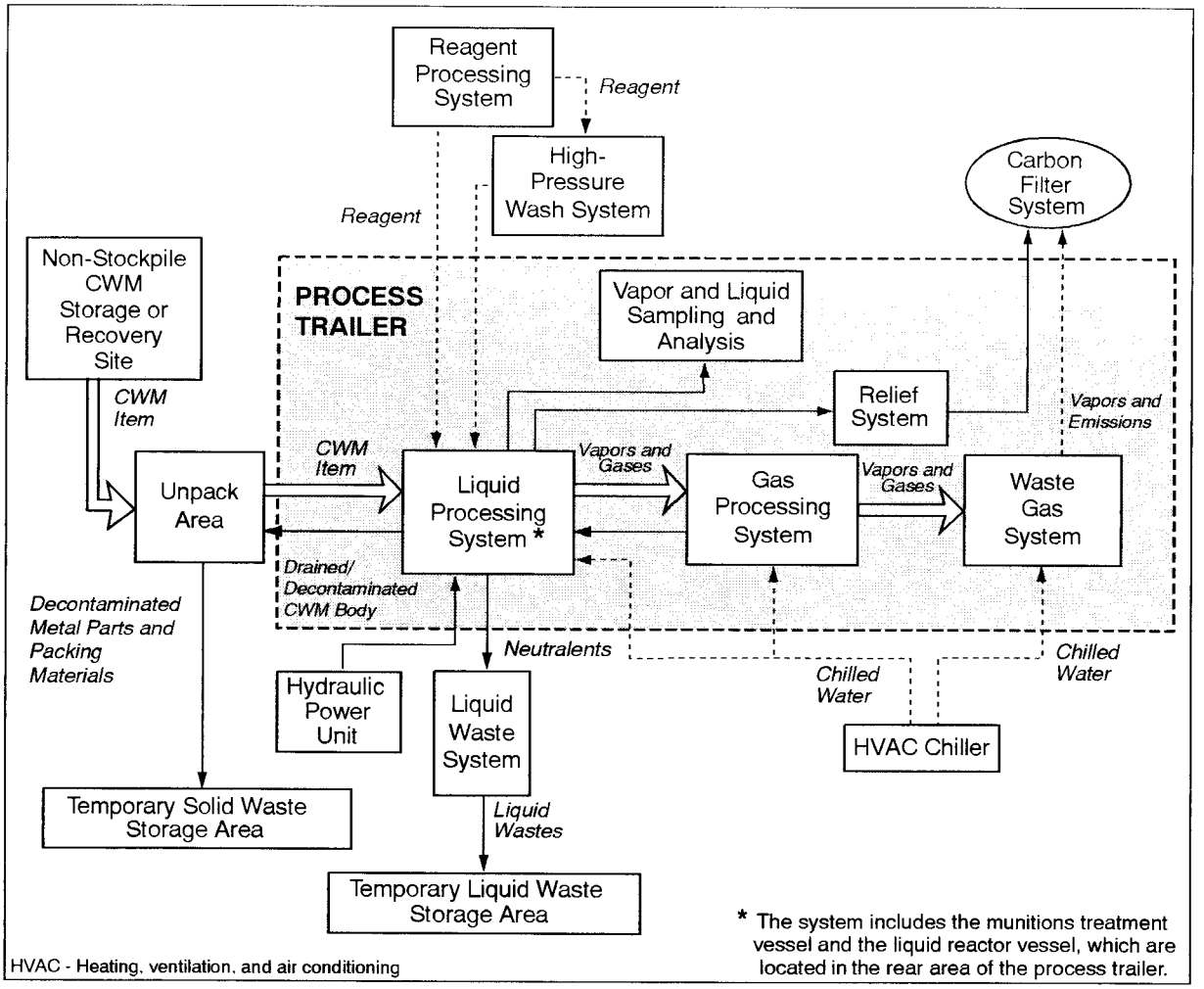


Figure C.3-2. Process Flow Diagram for the Munitions Management Device - Version One

C.3.2.1 Unpack Area

The unpack area is a transportable, prefabricated, single-story modular building that will be located in an environmental enclosure or building. The inside floor of the unpack area consists of an integral leak-tight sump beneath a stainless-steel raised floor grating. It will be equipped with a fire protection system and a hoist for lifting overpacked items, and will also contain work benches, a push cart, a saw, an abrasive blasting hood, and various other tools. The unpack area has ventilation louvers, an induction fan, and a portable activated carbon filter system at its exhaust outlet. It will be maintained under negative pressure to contain potential chemical materiel emissions. The interior air quality of the unpack area will be monitored using near–real-time monitors and confirmation monitors.

In the unpack area (Figure C.3-3), operating personnel dressed in PPE can safely unpack a CWM item from any overpack, examine the CWM item to ensure it can be processed in the MMD-1, seal any leaks in the CWM item, and install the CWM item onto a holding fixture so that it can be positioned remotely in the MTV, which is located in the process trailer. After processing in the MTV, a decontaminated munition or container will be returned to the unpack area for size reduction and abrasive cleaning. Waste generated from the abrasive cleaning, descaling, and size reduction of decontaminated munitions or containers will be packed in appropriate containers for disposal.

C.3.2.2 Process Trailer

The process trailer, shown in Figure C.3-4, is divided into two areas: a forward area containing electrical and instrumentation connector panels and a rear area containing all of the accessing and treatment processing equipment. The process trailer walls will provide both a liquid and vapor containment barrier. The trailer will be maintained under negative pressure during processing and treatment operations. Portions of the exterior walls are removable to assist in equipment maintenance. A compartment underneath the trailer contains connectors for electrical power and instrumentation cabling. The process trailer will have sampling and process piping penetration plates in the walls that allow operators to obtain liquid and vapor samples from the process without entering the process trailer. The trailer also will have a heating, ventilation, and air conditioning (HVAC) and humidity control system and a fire suppression system. The air discharged from the process trailer will be filtered by a carbon filter system. A swing-out jib crane is provided at the rear of the process trailer to assist in loading CWM items for processing. Other equipment located in the process trailer include video cameras, near–real-time monitors and monitoring lines, sample ports, intercoms, and HVAC air handlers. The forward portion of the process trailer contains logic control panels of the Digital Control and Instrumentation System (DCIS), which allows remote control of accessing and treatment operations from the control trailer. This compartment also contains a gas analyzer, which is used to confirm the identity of the chemical to be treated, and the valve and instrument cabinet containing hydraulic equipment utilized in the munition loading and breaching system. The gas analyzer, which consists of a gas chromatograph mass spectrometer, is an element of the MMD-1 sampling and monitoring system described in Section C.3.5. The

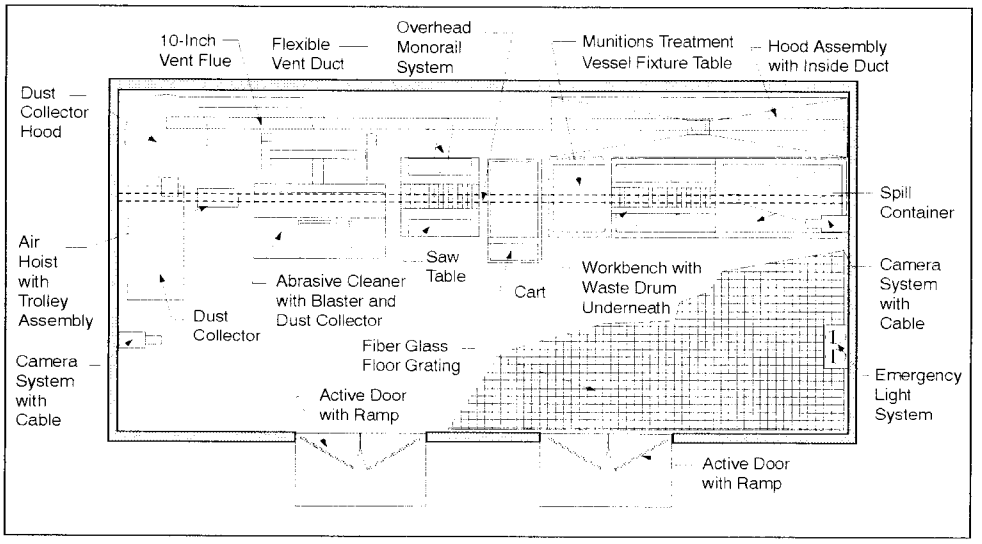


Figure C.3-3. Plan View of the Unpack Area of the Munitions Management Device - Version One

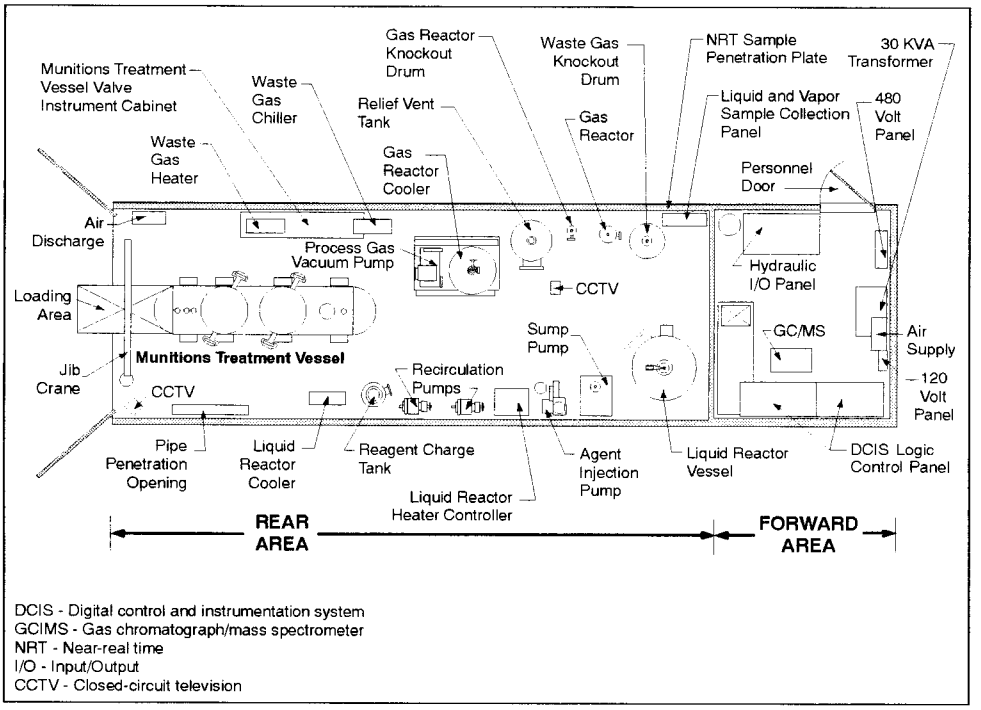


Figure C.3-4. Plan View of the Process Trailer of the Munitions Management Device - Version One

process trailer houses the MTV where processing of the CWM occurs. The MTV is a 280-gallon (1,060-liter) custom-fabricated, horizontal cylindrical pressure vessel that has two towers (Figure C.3-5), each of which contains the tools that are used to access the chemical fill in the munitions. Inside the MTV, the CWM munitions or containers are remotely accessed, the chemical fills are sampled and subsequently treated, and the carcasses are decontaminated. The associated processing subsystems include a munition loading and breaching system, a reagent processing system, a liquid processing system, a gas processing system, a waste gas processing system, a relief system, a liquid waste system, and a high-pressure wash system. The first seven subsystems are briefly described in the following paragraphs. The high-pressure wash system is discussed separately in Section C.3.1.3.

Munition Loading and Breaching System

The munition loading and breaching system provides the means to remotely access the chemical fills in non-stockpile CWM. The munition, on its holding fixture, will be placed on a carriage outside the MTV. The carriage will subsequently move the CWM item into position beneath cutting tools in the MTV. The door to the MTV will be closed, and the operators will leave the building. A remotely controlled (from the control room) clamp will hold the CWM item securely while a remotely operated cutting tool breaches the item. After the CWM item is breached, a vapor sample of the chemical fill will be drawn into an analyzer, which verifies the type of chemical so that the proper reagent solution can be prepared in the reagent processing system. The CWM item will then be rotated to allow the

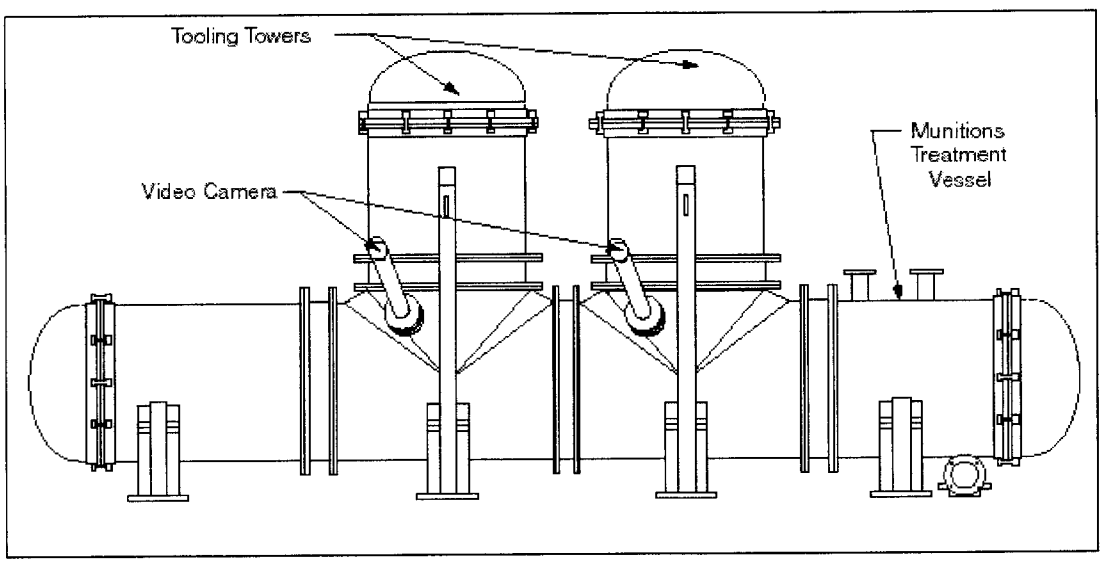


Figure C.3-5. Munitions Treatment Vessel in the Process Trailer of the Munitions Management Device–Version One

chemical fill to be drained into the MTV. Chemicals such as phosgene, which are normally gases at the system operating temperature, will be pumped by the waste gas vacuum pump through spargers in the LRV, where they will be mixed with the appropriate reagent solution. The tools and positioning devices will be powered by hydraulic and electric motors, and all the equipment in the process trailer will be operated remotely from the control trailer.

Reagent Processing System

The reagent processing system will supply the reagents that are used for the treatment of chemical fills in CWM items and for the cleaning and decontamination of MMD-1 equipment. This system will hold, mix, heat, and pump reagents to the liquid processing system. Once the chemical fill has been confirmed by taking and analyzing a vapor sample during initial accessing of a CWM item, the appropriate treatment reagent will be prepared in the reagent processing system and pumped into the liquid processing system. The reagent processing system is skid-mounted for transportability and located outside of the process trailer. It consists of two storage tanks; two motor-driven reagent pumps; and associated piping, valves, and instrumentation. One of the storage tanks has an electric heating jacket to heat liquid reagents when required for treating certain chemical fills. The other storage tank will normally hold process water used to clean the MMD-1 systems following treatment operations, but it also could be used as a backup for the other storage tank. A catch pan located underneath the tanks will provide secondary containment in the event of leaks from the tanks, pumps, or pipes. The system will be supplied with steam, nitrogen, electrical power, and instrument air from skids located outside of the process trailer. The reagent processing system will be controlled by the DCIS to allow control of the system from the control trailer. The reagent and water in the reagent storage tanks can be pumped to various locations in the liquid processing system. A pump bypass line allows transfer of liquid reagents using nitrogen pressure. The reagent storage tanks also serve as the supply source for the high-pressure wash system.

Liquid Processing System

Chemical fill drained from a CWM item will be treated in the liquid processing system by mixing the drained chemical fill with an appropriate treatment reagent in a controlled and safe manner. The primary components of the system include the MTV, the LRV, and process equipment. In addition to the cutting tools, the MTV has high- and low-pressure spray nozzles to remove residual material, CWM chemical fill, or reagent from its internal surfaces and the external surfaces of a CWM item with a reagent or water spray. The spray nozzles can also be supplied with hot water or steam. Video cameras located in each tower of the MTV allow operations to be monitored from the control trailer. Liquid and vapor process samples may be taken from the MTV through a sample panel located on the outside wall of the process trailer.

The LRV is a 375-gallon (1,420-liter) stainless steel tank that will be used to treat any gases emitted in the munitions treatment vessel, to treat high-vapor-pressure chemical fills (chemical fills that evaporate rapidly, such as phosgene), and to complete treatment of chemical fill by

mixing with an appropriate reagent that was started in the MTV. The LRV will also be used for heating treatment reagent solutions when necessary, as well as for holding partially spent treatment reagent for reuse and spent reagent and liquid wastes from system clean-out operations. The LRV has been instrumented with liquid level indicators, high-level switches, and remote temperature and pressure sensors that will be monitored from the control room.

The liquid processing system also contains two recirculation pumps, a liquid reactor cooler, and a steam condenser. The recirculation pumps, liquid reactor cooler, and steam condenser provide for recirculation, mixing, and temperature modulation. In most instances, the drained chemical agent fill will begin treatment in the MTV and will then be transferred—using nitrogen pressure—to the liquid reactor vessel if reagent heating or vigorous mixing will be required for final treatment of any trace agent fill remaining. The reagent charge tank will be used when small measured amounts of a chemical fill are required to control the rate of the treatment reaction by limiting the rate at which a chemical fill is combined with the treatment reagent, such as when treating phosgene.

Gas Processing System

The gas processing system will pump and treat chemical vapors from the MTV, the LRV, and the reagent charge tank. This system includes a process gas vacuum pump, a gas reactor cooler, a gas reactor knockout drum, a gas reactor, and a waste gas knockout drum. The gas reactor knockout drum will be used to reduce the moisture content of the vapor stream entering the gas reactor. The drum has a pressure relief valve. Vapors discharged from the gas reactor knockout drum will enter the gas reactor for treatment. The reactor contains a packed bed of activated carbon impregnated with sodium hydroxide that reacts with residual chemical fill in the vapor stream. Gases and vapors that have been reacted will then be discharged to the waste gas knockout drum. Liquids that accumulate in the gas reactor knockout drum and gas reactor will be drained to the LRV for treatment.

The waste gas knockout drum will separate entrained moisture in the vapor stream that has been discharged from the gas reactor and will provide a hold-test-release capability for the gas processing system before the vapor is discharged for final treatment in the waste gas system. The vapor stream can be recirculated for further treatment in the gas processing system as required. The drum has remote level, pressure, and temperature indications through the DCIS.

Waste Gas Processing System

The waste gas processing system will provide further treatment of chemical vapors prior to exhausting them to the process trailer carbon filter system. This system consists of a waste gas chiller, a waste gas heater, a vent knockout drum, and a carbon adsorber. Vapors that enter the waste gas system will be dried by cooling in the waste gas chiller and then heated in the waste gas heater to lower relative humidity. The vent knockout drum will remove moisture released during filling operations from the reagent tanks and surge tanks head-space vapor streams. The carbon adsorption unit will remove residual traces of CWM and volatile

compounds in the vapors before they are vented to the process trailer carbon filter system. The unit consists of two activated carbon-filled 55-gallon (208-liter) carbon steel canisters in series. One canister has an activated carbon bed that is specific to monoethanolamine (MEA) and volatile compounds, and the other canister has an activated carbon bed that is specific to chemical fills in CWM. A manual sampling port is available for gas sampling at the discharge from the carbon adsorption unit.

Relief System

The MTV will be protected by relief valves in the event that higher-than-expected pressure occurs in a tank. Any vapors released from the MTV will be captured and discharged to a relief vent tank. Vapors captured in the relief vent tank will be discharged to the LRV for treatment. In the event of a large pressure release, the relief vent tank is protected by a relief valve that will discharge vapors to the process trailer's carbon filter system. Relief valves on MMD-1 tanks and vessels other than the MTV will vent vapors to the process trailer's carbon filter system.

Liquid Waste System

Spent reagent (neutralents), spent decontamination solutions, rinse waters, and condensate generated from the MMD-1 treatment and decontamination operations will be temporarily stored in the liquid waste system. The liquid waste system consists of two surge tanks, a waste-transfer pump, and a sump pump located in the process trailer sump. The waste transfer pump will transfer liquid wastes from the surge tanks to containers meeting USDOT specifications or to the liquid processing system for additional treatment. Each of the surge tanks has local and remote pressure and temperature sensors, a level indicator, a level transmitter, an opening for inspections and manual cleaning, a manual drain valve, and a secondary containment pan.

C.3.2.3 Control Trailer

The control trailer is depicted in Figure C.3-6. The interior of the trailer is divided into four areas: a monitoring room, a control room, an electrical equipment room, and a storage area. The control trailer has several compartments for storing power cables, munition tooling fixtures, and spare parts. The trailer has a portable platform and stairs for access and a fire suppression system. The control trailer will house the following equipment and systems: DCIS, electrical supply distribution panel, an uninterruptible power supply system, and near–real-time monitoring equipment.

Monitoring Room—The near–real-time monitors for chemical fills (for example, MINICAMS®) will be located in the monitoring room, along with supporting equipment for the gas chromatograph mass spectrometer located in the forward area of the process trailer. The gas chromatograph mass spectrometer located in the process trailer will be used to analyze for chemical fill type and will be remotely operated from the control trailer. Air monitoring lines will run from the monitoring room to various sampling locations throughout the process system.

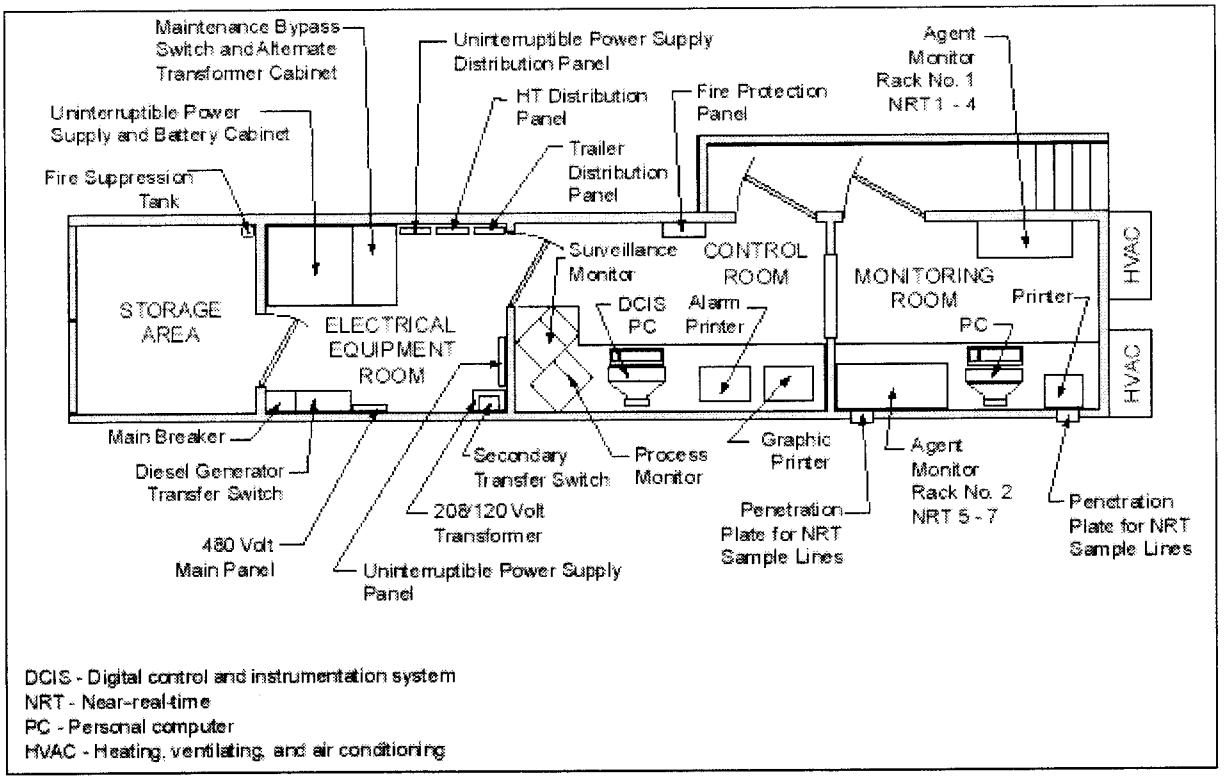


Figure C.3-6. Plan View of the Control Trailer of the Munitions Management Device–Version One

Control Room—The control room will contain the host computer for the DCIS. The DCIS is a computer-based data acquisition and control system that enables (1) control of the CWM accessing and treatment operations in the process trailer and (2) operation of the skid-mounted equipment necessary for process trailer operations from the control room. The DCIS will record MMD-1 process data (temperatures, pressures, flow rates, etc.). A closed-circuit television system will be available for operators to check the status of accessing operations and to provide surveillance of other systems.

Electrical Equipment Room—The electrical equipment room will contain the major electrical equipment for operating the MMD-1, including most of the elements of the electrical distribution system. The distribution system will consist of a 480-volt system, a 120-volt system, and an uninterruptible power supply system. The uninterruptible power supply system will provide continuous power to critical instruments and equipment (such as chemical agent monitors) in case of power failure.

C.3.2.4 Utility and Support Systems

Utility and support systems associated with the MMD-1 include a hydraulic power system, an instrument air system, a nitrogen generator, a 480-volt electrical power system, a

steam generation system, a high-pressure wash system, two carbon adsorption systems, a reagent storage tank system, a waste-and-surge storage system, a chiller system, a utility distribution system, and a standby diesel generator. These systems have been designed for outdoor operation and are skid-mounted for transport by flat bed trucks or trailers. The following subsections briefly describe these systems and their functions.

Hydraulic Power System —The hydraulic power system will provide hydraulic power for the breaching and accessing tools in the MTV. The skid contains a hydraulic pump and motor, a fluid reservoir, and instrumentation to monitor levels and temperatures.

Instrument Air System—The instrument air system will supply air to pneumatic-controlled devices such as air operated valves and will supply instrument air to a near–real-time monitoring dilution device, if required. This skid consists of air intake filters, motor-driven compressors, after-coolers, a receiver tank, desiccant dryers, filters, and self-regulating controls.

Nitrogen Generator—The nitrogen generator will supply nitrogen to the MTV, the LRV, the reagent charge tank, the relief vent tank, the surge tanks, and the reagent storage tanks to reduce oxygen concentration and to provide adequate pressure for pump operation. In addition, the recirculation pumps, reagent fill pumps, and waste transfer pump barrier fluid seal pressures will be maintained under nitrogen overpressure to prevent leakage of fluid out of the pumps. The main components of the system include a nitrogen generator, an air compressor, pressure and purity instrumentation, a moisture separator, a nitrogen receiver, filters, and self-regulating controls.

480-Volt Electrical Power System—The 480-volt electrical power distribution system will be an element of the electrical power distribution system that provides 480-volt electricity to all other skid-mounted equipment and 120-volt receptacles for distribution of 120V power.

Steam Generation System —The steam generation system skid contains an electric steam generator that will be used to supply steam and hot water to the MTV and LRV for cleaning and decontamination and to the waste gas heater for humidity control. The skid will be self-contained and include heating elements, pumps, a fluid reservoir, and control instrumentation.

High-Pressure Wash System—The high-pressure wash system skid will supply reagent or water at pressures up to 5,000 pounds per square inch (34,500 kilopascals) to the MTV. The pump will take suction from the reagent storage tanks and pump the reagent or water to nozzles in the MTV towers. The skid includes a strainer, a high-pressure positive displacement pump, control instrumentation, and rupture disks for overpressure protection. The pump pressure, the discharge pressure, and the temperature have local indicators and will be monitored by the DCIS. The system can be connected to a steam line if steam is required for cleaning the interior walls of a munition or container in the MTV.

Carbon Adsorption Systems—One of the carbon adsorption systems will provide final filtration of the air in the process trailer. It will consist of filter housings, pre-filters, high-

efficiency particulate air filters, high-efficiency gas adsorber filters, an exhaust duct, a blower, and dual motors (for backup capability). The filtration system consists of high-efficiency particulate air filters and activated carbon beds in series that are intended as safeguard devices. The filter elements are capable of adsorbing toxic chemicals in gas streams from the liquid and gas processing systems and the process trailer workspace that could potentially bypass the process system. The system will be monitored for chemical agent and industrial chemical contamination. All the filters in the process trailer carbon filtration unit are of the bag-in and bag-out type, which allows filter elements to be removed and replaced from the exterior of the filter housing without exposing personnel to the contents of the spent filter elements or releasing hazardous chemicals to the environment. To prevent the release of hazardous chemicals outside of the trailer, the process trailer carbon filtration unit maintains the process trailer under negative pressure at all times.

The second carbon adsorption unit is part of the waste gas processing system that was described in Section C.3.1.2. The unit consists of two skid-mounted activated carbon-filled 55-gallon (208-liter) carbon steel canisters in series. One canister has an activated carbon bed that is specific to MEA and volatile compounds, and the other canister has an activated carbon bed that is specific to chemical fills.

Reagent Storage Tank System—The reagent storage tank system consists of two 250-gallon (946-liter) carbon steel tanks and two reagent fill pumps on a single skid. This system will maintain a sufficient volume of fresh treatment reagents and water to supply the liquid processing system during treatment operations and cleaning. The skid has been designed with secondary containment to capture spills.

Waste-and-Surge Storage Tank System—The waste-and-surge storage tank system will receive the treated liquid wastes (neutralents) or reagents from the MTV, the LRV, the reagent storage tank, and the sump pump. This system consists of two identical tanks and a single motor-driven centrifugal pump that can pump the waste to USDOT containers or back to the reagent processing system for re-treatment, if necessary.

Chiller System—The chiller, part of the HVAC system of the process trailer, operates with a 50/50 water/glycol mixture. It will provide chilled water to the process trailer air-handling units for trailer environmental cooling and to the various heat exchangers in the process trailer for process treatment cooling, in particular to (1) the reagent fill pumps, (2) the recirculation pumps and waste transfer pump's barrier cooling coils, (3) the liquid reactor cooler, (4) the gas reactor cooler, and (5) the waste gas cooler. The HVAC chiller can produce 105 kilowatts (360,000 British thermal units per hour) of air conditioning and water for process and environmental cooling. The HVAC skid contains distribution piping for chilled water going to the process trailer.

Utility Distribution System—The utility skid and the HVAC skid will provide headers for portions of the utility systems such as process water, cooling water, air, and nitrogen, and thus, act as an interface between the process trailer and the other skids.

Standby Diesel Generator—The standby diesel generator will provide a backup capability in the event that there is a failure of the primary electrical power supply used by the MMD-1. The generator is rated at 125 kilowatts. A 130-gallon (492-liter) double-walled fuel tank will be provided with the diesel generator. An automatic transfer switch will start the generator when there has been a loss of power.

C.3.2.5 Environmental Enclosure

An environmental enclosure will be used in conjunction with the MMD-1 at sites where no existing buildings or structures are available in which to locate those components of the MMD-1 having the potential for internal chemical materiel contamination. The environmental enclosure will include flexible walls over a rigid framework and a portable groundcover liner. Interlocking pierced steel planking will be placed in the structure for concentrated load areas (for example, the operations trailer) and an expanded metal mat floor surface will be placed where forklifts or other vehicles travel inside the enclosure. Footings and appropriate curbing will be poured, if required. The enclosure will have an HVAC system to provide heating, cooling, and humidity control, as well as a charcoal-type filtration system to filter the air passing out of the environmental enclosure. The filtration system for the enclosure will have the capability to receive the discharge from the process trailer exhaust port. Panels built into the walls of the enclosure will allow for penetrations of electrical and other support service lines. A forklift battery charging station will also be contained in the environmental enclosure.

An airlock will provide for entrance and egress of personnel. Within the airlock, sufficient space will be provided for personnel to change into and out of PPE, and a shower will be available for decontaminating the exterior of PPE. A second airlock will be provided to accommodate the movement of vehicles and equipment into and out of the enclosure.

C.3.3 Treatment Chemistry

The following subsection describes the planned MMD-1 treatment chemistry.

The treatment processes in the MMD-1 are based on chemical neutralization processes designed to convert chemical agents into chemical compounds that could be released from Army control, transported, and further treated using processes similar to that used for industrial chemical wastes. As listed in Table C.3-1, the treatment reagents that will be used in the MMD-1 comprise (1) MEA in water for HD and GB, (2) a mixture of MEA and sodium hydroxide in water for the nerve agent VX, and (3) sodium hydroxide in water for phosgene.

Table C.3-1. Neutralent Wastes from the Munitions Management Device–Version One

Chemical	Treatment Reagent	Waste Stream	
		Waste Component	Percent
Sarin GB	Water (55 percent) MEA (45 percent)	Water	50
		Monoethanolamine, MEA	30
		Monoethanolamine hydrofluoride + 2-hydroxyethylammonium isopropyl methylphosphonate	10
		Isopropyl methylphosphonic acid, IMPA	7
		O-isopropyl O'-(2-aminoethyl)methylphosphonate (GB-MEA complex)	3
		Diisopropyl methylphosphonate, DIMP	<1
		Tributylamine	<1
		N,N'-Diisopropyl urea	<1
		GB	<1 ppm
Mustard HD	MEA (90 percent) Water (10 percent)	Monoethanolamine, MEA	60
		Monoethanolamine hydrochloride	20
		Water	10
		N-(2-hydroxyethyl)thiomorpholine, HETM	8-9
		Bis-(2-hydroxyethylaminoethyl)sulfide, HEAES	1-2
		1,4-dithiane	<1
		Chlorinated thiophenes	<1
		HD	<1 ppm
VX	MEA (85 percent) Sodium hydroxide (7.5 percent) Water (7.5 percent)	Monoethanolamine, MEA	78-83
		Water	7
		Sodium hydroxide	4.2–6.3
		Sodium 2-diisopropylaminoethanethiolate, NaThiol	1.4–.5
		Sodium O-(2-aminoethyl) methylphosphonate, NaAEMPA	0.5-1.8
		Sodium O-ethylmethylphosphonate, NaEMPA	0.6-2.0
		Disodium methylphosphonate, Na2MPA	0.15-0.5
		Bis-(2-diisopropylaminoethyl)sulfide, SULFIDE	0.22-0.71
		Bis-(2-diisopropylaminoethyl)disulfide, DISULFIDE	0.13-0.41
		2-Diisopropylaminoethyl ethyl sulfide	0.03-0.09
		1,3-dicyclohexylurea	0.1-0.35
		Ethanol	0.2-0.7
		Unquantified identified products	0.4-1.0
		VX	<1 ppm
Phosgene CG	Water (90 percent) Sodium hydroxide (10 percent)	Water	90
		Sodium hydroxide, NaOH	8-9
		Sodium carbonate, Na_2CO_3	1-2
		Sodium chloride, NaCl	1-2

MEA—Monoethanolamine

MEA is an organic solvent that has been used in applications such as dry cleaning detergents, the synthesis of ammonia from gas streams, and the treatment of wool and polishes. MEA was approved as a major decontaminating solution for use at U.S. chemical surety facilities and was extensively studied in the 1970s (Brankowitz, 1978) during the initial program for the demilitarization of the national stockpile.

MEA has several advantages when used to treat chemical agents in the MMD-1. MEA has a relatively high flash point (the lowest temperature at which MEA gives off vapor that will ignite upon the application of a small flame is high), and MEA is also non-corrosive to metals, inexpensive, and relatively stable. The reaction of MEA with chemical agents results in the formation of a homogeneous solution of relatively few reaction products.

Sodium hydroxide, sometimes referred to as caustic soda or lye, is one of the most widely produced commercial chemicals. It is used in the manufacture of soaps, detergents, and paper, and is also used in vegetable oil refining. Solutions of sodium hydroxide in water have been used by the Army as a chemical warfare agent decontaminant since World War I.

The chemistries of the treatment of GB and HD with MEA and water, and the treatment of the nerve agent VX with MEA, sodium hydroxide, and water have been fully documented with regards to their effectiveness as part of the development of the MMD-1 (Department of the Army, 1997g; Department of the Army, 1997h; Department of the Army, 1997i; Department of the Army 1997j; Department of the Army, 1997k; Department of the Army, 1997l). Dermal toxicity skin injury and vesication studies have also been completed with nuetralized HD wastestreams (Department of the Army, 1997g; Department of the Army, 1997h; Department of the Army, 1997i). Studies of the chemistries for the neutralization of other mustards (e.g., nitrogen mustards) and nerve agents (e.g., tabun) have not been completed, but it is expected that the results will be similar to the results for those that have been completed.

The reaction of phosgene with sodium hydroxide and water is rapid, while the reaction of other chemical agents with treatment reagents is slow, requiring up to 4 hours for HD. The reaction time for HD can be significantly reduced by increasing the initial temperature of the reacting mixture to approximately 122 °F (50 °C). The increase in reaction temperature during the course of the reaction is relatively mild, with peak temperatures under 200 °F (93.3 °C). Table C.3-2 lists the reaction parameters for the different processes to be used in the MMD-1.

The resultant neutralents following the reaction of MEA and water with HD and GB, and the reaction of MEA, water, and sodium hydroxide with VX will contain mostly residual MEA and water. Major reaction byproducts in the neutralent of the reaction of MEA and water with HD will include 2-hydroxyethylammonium chloride, N-(2-hydroxyethyl)-thiomorpholine, bis-[(2-hydroxyethylamino) ethyl] sulfide, and other organic sulfides. The major reaction byproducts of MEA and water with GB will include 2-hydroxyethylammonium O-isopropyl methylphosphonate salt, 2-hydroxyethylammonium fluoride, and isopropyl

Table C.3-2. Reaction Parameters for the Chemistry Processes for the Munitions Management Device-Version One

Chemical	Reaction Parameters					
	Starting Temperature		Peak Temperature[a]		Time Required to Destroy 99.8 Percent	Experimental Range During Testing[c]
	C°	F°	C°	F°		
Sulfur Mustard (HD)	50	122	79.4	175	About 1 hour at 50°C[b]	30 to 240 min
Sarin (GB)	24 to 32	76 to 90	43 to 52	109 to 126	Less than 3 hours at between 24 to 52°C	15 to 60 min
VX	45 to 52	113 to 125	Continuous heating required		Less than 2 hours at between 45 to 52°C	15 to 240 min
Phosgene	Less than 34	Less than 93	-16 to 23	3 to 73	Rapid	10 to 30 min

[a] Temperature measured in the neutralent solution.

[b] Time required at ambient temperatures up to 4 hours.

[c] MMD-1 RD&D Draft RCRA Permit, December 1998.

2-aminoethyl methylphosphonate. The reaction of MEA, sodium hydroxide, and water with VX will result in a neutralent solution containing mostly residual sodium hydroxide. The major byproducts of the reaction include sodium 2-diisopropylaminoethanethiolate, sodium O-ethyl methylphosphonate, and sodium O-(2-aminoethyl) methylphosphonate. Table C.3-1 lists the major reaction byproducts and other constituents in the neutralents from the treatment of HD, GB, VX, and phosgene. As indicated in Table C.3-1, the residual concentration of HD, GB, VX, and phosgene will be less than 1 part per million.

Similar to the studies conducted for RRS neutralents, dermal toxicity tests and dermal irritation studies (Department of the Army, 1997g; Department of the Army, 1997h; Department of the Army, 1997i) were conducted in accordance with Organization for Economic Cooperation and Development guidelines to ascertain the systemic and skin-injury potential of MMD-1 neutralents from the treatment of HD, GB, and VX. Quantitative analysis of skin irritation response data for short-term acute dermal toxicity tests and dermal irritation studies indicated that skin irritant effects from the HD, GB, and VX neutralents were either comparable to or lower than those observed from the neutralization reagents (MEA and water, and MEA, water, and sodium hydroxide) alone, and could be transported as Packing Group III materials (those presenting minor danger). Vesication studies with neutralents from the neutralization of HD (Department of the Army, 1997j) indicated that HD neutralents were non-vesicating.

C.3.4 Wastes and Emissions

The subsections that follow discuss the wastes and air emissions that may be generated from MMD-1 processing and treatment operations; the discussion is based on the information in the RCRA permit application for testing of the MMD-1 prototype system (Department of the Army, 1997m), the detailed facility information for the testing of the MMD-1 prototype (Department of the Army, 1997o), and the monitoring concept plan for buried CWM (Department of the Army, 1997f). During normal operation of the MMD-1, no liquid effluents will be discharged to surface water or groundwater except for operational personnel sanitary waste, for which either existing sanitary systems or portable facilities will be used.

C.3.4.1 Wastes

Several wastes will be generated from MMD-1 treatment operations, including (1) the spent reagent (neutralents) generated from treatment of chemical fills, (2) decontaminated packing materials, metal containers, and munition casings, (3) uncontaminated packaging materials, (4) spent decontamination solutions and rinse waters, (5) spent carbon and filter elements, (6) recontainerized industrial chemicals from industrial chemical fills not treated in the MMD-1, (7) spent cleanup materials, trash, and debris, (8) used PPE, (9) spent hydraulic fluid, (10) spent coolant/chiller fluids, (11) bead blast residue, and (12) spent pump reservoir fluids. Table C.3-3 lists the wastes that will be generated during MMD-1 operations, the activity or process that will generate each waste, and the physical state of each waste. Table C.3-1 lists the constituents of the neutralent wastes.

All wastes generated from MMD-1 operations will be appropriately containerized and characterized. All wastes that may be contaminated with chemical agent will be sampled and analyzed for chemical agent concentration.

Phosgene is a RCRA-listed hazardous waste (40 CFR 261.33). Wastes generated from the treatment and decontamination of chemical agent (neutralents, spent decontamination solutions, decontaminated packing materials, etc.) may contain RCRA characteristic chemicals above regulatory levels. Such chemicals could include toxicity characteristic metals—such as selenium (D010) and mercury (D009) that have been found as impurities in chemical agent—and various toxicity characteristic organic chemicals such as benzene (D018); carbon tetrachloride (D019); 1,2-dichloroethane (D028); 1,1-dichloroethane (D029); 2,4-dinitrotoluene (D030); hexachlorobenzene (D032); hexachlorobutadiene (D033), hexachloroethane (D034); nitrobenzene (D036); tetrachloroethylene (D039); trichloroethylene(D040); 2,4,6-trichlorophenol (D042); and vinyl chloride (D043). These organic chemicals have been identified in neutralents from toxicity characteristic leaching procedure analyses conducted as part of the documentation of the MMD-1 treatment chemistries (Department of the Army, 1997g; Department of the Army, 1997h; Department of the Army, 1997i). Because neutralent wastes may exhibit the RCRA characteristic of corrosivity (D002), waste characterization analysis will be performed to determine if neutralents exhibit this characteristic. Neutralent

Table C.3-3. Waste Streams from the Munitions Management Device-Version One

Waste Stream	Process of Generation	Physical State	Location for Waste Management[e]
Neutralents	Chemical treatment of chemical agent fills	Liquid[b]	Permitted commercial hazardous waste treatment, storage, and disposal facility (TSDF).
Neutralents	Chemical treatment of industrial chemical fills	Liquid[c]	Permitted commercial hazardous waste TSDF.
Repackaged industrial chemicals	Draining and transferring industrial chemical fills from munitions or containers to appropriate shipping containers	Varies[d] (solid/liquid)	Permitted commercial hazardous waste TSDF.
Decontaminated overpacks, metal containers, munition casings, and metallic packing materials	Decontamination of chemical agent contaminated overpacks. metal containers, munition casings, and packing materials	Solid (may contain free liquids)	Recycling facility (Rock Island Arsenal or similar DoD facility). Otherwise, permitted commercial hazardous waste TSDF.
Decontaminated non-metallic packing materials	Decontamination of non-metal packing materials contaminated by agent	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Non-agent contaminated metal containers and munition casings	Processing of munition casings and containers with industrial chemical fills (following draining of the fill)	Solid	Recycling facility (Rock Island Arsenal or similar DoD facility). Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated overpacks	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid (may contain free liquids)	Cleaned and reused. Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated packing materials	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Uncontaminated overpacks	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Reuse.

Table C.3-3. (Continued)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[e]
Uncontaminated packing materials	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Permitted solid waste landfill.
Spent decontamination solutions and rinse waters	Decontamination, cleaning, and rinsing operations (including emergency personnel decontamination station)	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility
Bead blast residue	Abrasive cleaning and descaling of decontaminated metal munitions bodies and parts from munitions with chemical agent fills	Solid	Permitted commercial hazardous waste TSDF.
Bead blast residue	Abrasive cleaning and descaling of decontaminated metal munitions bodies and parts from munitions with industrial chemical fills	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Spent carbon and other filter elements	Change-out of filter elements and carbon from filtration units associated with the processing of chemical agent (for example, carbon filtration unit and carbon adsorption unit)	Solid	Permitted commercial hazardous waste TSDF.
Other spent filters	Change-out and replacement of filter elements not associated with the processing of chemical agent	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Used personal protective equipment[f]	Personal protective equipment generated from treatment system operations	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Laboratory wastes	Laboratory activities (for example, analysis, calibration, maintenance, and cleaning); spent chemicals and materials	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.

Table C.3-3. (Concluded)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[e]
Spent cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
HVAC condensate	Use of HVAC systems	Liquid	Tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in containers for subsequent treatment at an existing wastewater treatment facility.
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Includes wastes from the pre-operational survey.

[b] The neutralent waste generated would be dependent upon the chemical agent fills of the chemical munitions to be treated at each site location.

[c] The neutralent waste generated would be dependent upon the industrial chemical fills of the munitions to be treated at each site location.

[d] The physical state would vary depending on the industrial chemical present.

[e] Wastes would be tested for the presence of chemical agent. If present, the waste would be decontaminated and, except for decontaminated overpacks, metal containers, munition casings, and packing materials, would be sent to a permitted commercial hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

[f] Single-use PPE would be disposed. Multi-use (reusable) PPE might be cleaned and reused rather than disposed. This would be a site-specific decision based on such factors as practicality, cost-effectiveness, integrity of the item, and availability of laundry facilities.

HVAC—Heating, ventilating, and air conditioning

TSDF—Treatment, storage and disposal facility

waste exhibiting the characteristic of corrosivity will be classified with the RCRA waste code D002. Actual waste characterization analysis or generator knowledge gained from sampling and analysis of the waste streams generated during the testing of the prototype MMD-1 will be used to classify the wastes generated from MMD-1 operations. In addition, in some states, wastes generated from chemical agent demilitarization operations are state-listed hazardous wastes and must be managed as such within that state.

In addition to the process and treatment wastes, waste such as fuel oil, spent fuel filters, and oil-contaminated rags may be generated from MMD-1 maintenance activities. These wastes will be appropriately containerized, characterized, and stored pending ultimate disposition.

Based on processing and treating two CWM munition or container each day, it is estimated that the MMD-1 will generate up to 600 gallons (2,272 liters) of liquid neutralent per day that will be containerized in 55-gallon (208-liter) drums or 350-gallon (1,325-liter) totes. The estimated solid waste generated for each munition will include one 55-gallon (208-liter) drum containing metal from munition casings or containers and bead blast residue material from the unpack area, one 55-gallon (208-liter) drum containing sludge or sediment from strainers from the process area, and one 55-gallon (208-liter) drum containing used PPE and similar waste from the site.

C.3.4.2 Emissions

The potential sources of emissions to the air from MMD-1 operations include those from the operation of diesel generators for electrical power supply, from the process trailer and unpack area ventilation systems to within the environmental enclosure, and from the environmental enclosure ventilation system.

Diesel Generators

As currently designed, the MMD-1 will require 480 kilowatts during normal operation that will be provided by a local electrical power supply system, if available. If a source of local electrical power supply is unavailable, a generating system will be required at the treatment site. A standby diesel-powered generator rated at 125 kilowatts of continuous power will be used to complete a treatment process in the MMD-1 or to safely shut down MMD-1 operations in the event of a failure of the local power system or generating system. Periodic maintenance of the diesel-powered generator will be performed to sustain efficient operation. The standby diesel-powered generator and a generator for normal power, if required, will discharge engine combustion gases and particulate matter.

Process Trailer

The MMD-1 process trailer has been designed to conduct treatment operations under negative pressure and several levels of containment to control the potential release of hazardous contaminants to the environment. The emission point from the process trailer to the environmental enclosure will be the exhaust stack from the carbon filtration unit. The

carbon filter system has been designed with redundant high-efficiency particulate air and carbon filter elements to capture the specific chemicals that will be handled in the MMD-1. These redundant filters coupled with the near–real-time monitoring between the filter elements will be used to control and limit the potential release of hazardous concentrations of chemical agent and chemicals into the environmental enclosure.

Unpack Area

The MMD-1 unpack area has been designed to conduct unpacking, leak sealing, decontaminating, abrasive cleaning, and containerizing of munition bodies in a controlled environment. The unpack area will be maintained under negative pressure and several levels of containment to control the potential release of hazardous contaminants to the environment. The emission point from the unpack area to the environmental enclosure will be the exhaust from its carbon filter system, which controls and limits the potential release of hazardous concentrations of chemical agent and chemicals into the environmental enclosure. The interior air quality of the unpack area will be monitored using near–real-time monitors (MINICAMS®) and confirmation monitors.

Environmental Enclosure

The components of the MMD-1 system that have the potential for internal chemical materiel contamination will be located in an environmental enclosure or an existing appropriate building. The enclosure or building will provide an additional measure of vapor containment in the event of a spill or accidental release during handling or processing. The environmental enclosure or building will have its own carbon filter on its air exhaust to further control potential emissions to the atmosphere of hazardous concentrations of chemical agent and chemicals, including any vapors escaping from the process trailer or the unpack area.

C.3.5 Monitoring Systems

Air monitoring will be conducted to ensure public and worker safety. The monitoring systems for the MMD-1 will comprise two types of air monitors: (1) near–real-time monitors using MINICAMS® and (2) confirmation and historical monitors using a depot area air monitoring system (DAAMS) and colorimetric tubes.

C.3.5.1 Near–Real-Time Air Monitoring System

Multiple MINICAMS® will provide air monitoring during MMD-1 operations. The MINICAMS® will be configured to detect HD, GB, VX, phosgene, and other chemical agents and industrial chemicals that may be considered for treatment in the MMD-1 after prototype testing. The MINICAMS® will be the primary system used to warn MMD-1 operating personnel of a potential airborne exposure hazard. The MINICAMS® will be set to alarm when the ambient air concentration exceeds a specific level, at most 70 percent of the control limit (see Table C.3-4).

Table C.3-4. Control Limits for the Munitions Management Device-Version One[a]

Chemical Materiel	Control Limits[e]	
	mg/m^3[b]	ppm/v[b]
Sulfur Mustard (HD)	0.003	0.00045[c,d]
Sarin (GB)	0.0001	0.00002[c,d]
VX	0.00001	0.0000009[c,d]
Phosgene	0.4	0.1[c]

[a] Workplace exposure level is an umbrella term encompassing all limits, including the 8-hour time-weighted average, the permissible exposure limit, the threshold limit value, and other levels developed to protect the worker during normal operations.
[b] Milligrams per cubic meter (mg/m^3) or parts per million by volume (ppm/v) at 20° C and 1 atmosphere.
[c] Value based on 8-hour time-weighted average.
[d] No individual will be intentionally exposed to direct skin or eye contact with any amount of solid or liquid agent, or to solid materials contaminated with chemical agent.
[e] MINICAMS® would be set to alarm at a specific level that would not be more than 70 percent of the control limit.
Source: Department of the Army, 1997f.

Each of the MINICAMS® will have a different configuration, allowing monitoring of various chemicals. The GB and VX MINICAMS® will be configured with a flame photometric device with a specific band pass filter for phosphorus detection, while the HD MINICAMS® will be configured with a photometric device with a specific band filter for sulfur detection. Phosgene will be analyzed with a MINICAMS® configured with a halogen-selective detector to detect and quantify the chlorine in phosgene's chemical structure. For VX monitoring, the VX is converted to a more volatile compound similar in chemical structure to GB by using a silver fluoride polyester conversion pad (called a "V to G conversion pad") placed at the sample inlet of the heat-traced sample line. The analog for VX and GB both contain the phosphorous element used for flame photometric detection and therefore, can be assayed with the same MINICAMS®. Support equipment for the MINICAMS® will include a stream selection device, heat-traced sample lines, stack gas conditioning systems, vacuum pumps, mass flow meters, and a computer and printer interface (Department of the Army, 1996d).

The MINICAMS® will automatically send a report on the concentration of a chemical agent or industrial chemical in the sampled environment to the printer/floppy disk. The report includes the date, time, instrument number, sampling port number, chemical materiel identity, summary, MINICAMS® operational mode, and the chromatographic information. At the end of each operational day, the report will be collected from the printer and filed in the MMD-1 air monitoring files (Department of the Army, 1996d).

Selected MINICAMS® will also be able to activate a chemical alarm or a malfunction alarm on an annunciator panel if the system operates outside of parameter limits (flow, temperature, time, etc.) established by the operator. All MINICAMS® alarms will be monitored by the air monitoring personnel located in the control trailer.

Table C.3-5 lists the areas that will be monitored by the MINICAMS® for the chemical agent or industrial chemical being processed.

C.3.5.2 Depot Area Air Monitoring System

The MMD-1 DAAMS will consist of a vacuum pump, a sequencer, sample tubes, and a gas chromatograph. The vacuum pump will be used to continuously draw air through a sampling tube containing a solid adsorbent (HayeSep®D, Tenax-TA®, or Chromosorb 106). The sequencers in the sampling station will permit collecting samples over discrete, preset time periods. For MMD-1 operations, the sample stations will contain sample tubes to support historical and confirmation sample collection. This approach will allow two tubes to be collected for each operational shift and one tube to be used for quality control. At the beginning of the workday, or following a collocated MINICAMS® alarm, the tubes will be collected and analyzed using the gas chromatograph in the mobile chemical laboratory (Department of the Army, 1996d).

The DAAMS stations will perform two functions. First, the stations that are collocated with the MINICAMS® will function as the primary means for confirming a chemical agent MINICAMS® alarm. Second, the stations will function as the primary means of chemical agent detection for quality control and historical analysis in situations where a MINICAMS® is not collocated (for example, the mobile chemical laboratory). If a MINICAMS® is not being used as a primary monitor, DAAMS stations will be configured with duplicate sample tubes (Department of the Army, 1996d).

DAAMS station locations are listed in Table C.3-5.

C.3.5.3 Colorimetric Tube Monitoring

Colorimetric tube collection ports will be located at each DAAMS station. The colorimetric tubes will be used and analyzed as a confirmation analysis in response to a phosgene MINICAMS® alarm (Department of the Army, 1996d).

C.3.6 Required Resources

Assembly of the MMD-1 trailer units and skid-mounted support equipment will require approximately 1.5 acres (0.6 hectares) of level land. Approximately 40 personnel will be required to assemble the system; assembly may take up to two months. On average, 20 personnel will be required for operating the MMD-1. Two crews (a total of 40 personnel) will be expected to be available for operations that will occur at remote locations. Crew members will be composed of engineers, scientists, and certified operators, including the following:

Table C.3-5. Air Monitoring Locations and Equipment for the Munitions Management Device-Version One

Monitoring Location	MINICAMS®	Confirmation DAAMS/CT Sample	Historical DAAMS Sample
Environmental enclosure	Yes	Yes	Yes
Between carbon absorption units	Yes	Yes	No
Process trailer interior	Yes	Yes	Yes
Munition Treatment Vessel interior	Yes	No	No
Between process trailer carbon filter elements	Yes	Yes	No
Munitions service magazine	Yes	Yes	No
Between unpack area carbon filter elements	Yes	Yes	No
Unpack area interior	Yes	Yes	Yes
Anteroom interior	Yes	Yes	No
Between environmental enclosure filter elements[a]	Yes	Yes	No
Environmental enclosure filter exhaust[a]	Yes	Yes	Yes
Mobile chemical laboratory interior	No	No	Yes
Mobile chemical laboratory filter midbed	No	No	Yes
Mobile chemical laboratory filter exhaust	No	No	Yes
Unpack area gross level	Yes	No	No

[a]If required

CT–Colorimetric tube
DAAMS–Depot area air monitoring system

- MMD-1 manager (chemical or environmental engineer)
- Site safety officer (environmental compliance and safety professional)
- Equipment maintenance (mechanical, electrical, or hydraulics engineer)
- Logistics manager (maintenance and supply experience)
- Command post and communications operator (administrative and logistics experience)
- Control room operator (engineer)
- Laboratory operators (chemist and laboratory technicians certified on MINICAMS®)
- Unexploded ordnance technicians (senior explosive ordnance disposal qualified personnel for unpack area operations)
- Monitoring specialists (certified MINICAMS® operators)
- Chemical technicians (chemical equipment operators, personnel decontamination station operators, waste handlers)

Engineers and technicians from the U.S. Army Ammunition Equipment Directorate and the Edgewood Chemical and Biological Center will be available to assist the MMD-1 crew, if required.

About 480 kilowatts of power will be required to operate the MMD-1. Water will be required for the following MMD-1 processes and activities: treatment reagent preparation, lavatory facilities, emergency personnel decontamination, drinking water supply, cleaning and decontamination operations, and system closure operations. It is estimated that a maximum of about 2,000 gallons (7,570 liters) of water per day will be required during operation. Existing water supply systems will be utilized when available; otherwise, transportable potable water tanks will be used rather than establishing a new water supply system. Existing sanitary facilities will also be used when available, and transportable sanitary facilities will be used when sanitary facilities are not available.

C.4 Munitions Management Device—Version Two

The Munitions Management Device–Version 2 (MMD-2) is a transportable system designed to safely process non-stockpile CWM munitions with and without explosive components and certain containers used for shipping and storage of chemical agents. The MMD-2 would be capable of processing CWM munitions and containers that have a maximum diameter ranging from 2 inches (5 centimeters) to 8 inches (20 centimeters). With the addition of bulk item accessing equipment, the MMD-2 would be capable of processing larger (bulk) items with diameters ranging from 7 inches (18 centimeters) to 31 inches (76 centimeters), such as ton containers, large bombs (for example, 1,000-pound bombs), USDOT bottles. The MMD-2 would be transportable by road, rail, and barge.

The MMD-2 is designed to treat chemical munitions, containers, and bulk items containing mustard and the nerve agents sarin and VX, repackage CWM containing cyanogen chloride and chlorine, and either treat or repackage phosgene. Mustard agent is expected to be the predominant fill of the munitions and containers to be treated. The MMD-2 may encounter other chemicals within the specified munitions that require processing. The MMD-2 would have the flexibility to handle such chemicals within the envelope of the basic design, provided a pre-evaluation is performed prior to attempting to neutralize or repackage them.

The current design of the MMD-2 processing system consists of several transportable trailer units and various utility and support systems (see Figure C.4-1). The trailer units include (1) an unpack area, (2) an explosive containment chamber, (3) a chemical processing system, (4) a chemical supply system, (5) a neutralized waste system, (6) a bulk item processing system, (7) a detonation chamber, (8) a control trailer, (9) support systems and equipment, and (10) an environmental enclosure. Other support facilities and equipment would also be required to operate at a site, as shown on Figure C.4-1.

All MMD-2 chemical fill accessing and treatment operations in the chemical processing trailer would be controlled and monitored from the control trailer. Those components of the MMD-2 system that have the potential for internal chemical agent contamination would be located in an environmental enclosure that is being designed specifically for use with the MMD-2. The environmental enclosure would primarily provide climate control and protection from the elements for the processing operation inside the enclosure. It would also provide additional chemical vapor containment, although that is not its primary purpose. The environmental enclosure would have its own air filtration system, chemical agent air monitoring equipment, and internal lighting.

The following subsections of this appendix describe treatment operations (Section C.4.1), the major MMD-2 components and systems (Section C.4.2), treatment chemistry (Section C.4.3), the wastes and emissions that would be generated during MMD-2 operations (Section C.4.4), monitoring systems (Section C.4.5), the resources required during operation (Section C.4.6), and the regulatory design and operating features incorporated into the system, (Section C.4.7).

C.4.1 Treatment Operations

Figure C.4-2 presents a process flow diagram of MMD-2 operations. Non-stockpile CWM would be brought to the munition warming cabinet, if necessary, and then brought to the unpack area trailer. In the unpack area trailer, they would be removed from their overpack, placed into a cradle or holder to facilitate subsequent processing, and x-rayed as appropriate to verify the internal configuration of the munitions and to assist in determining appropriate locations for accessing the chemical fill contained in the munitions.

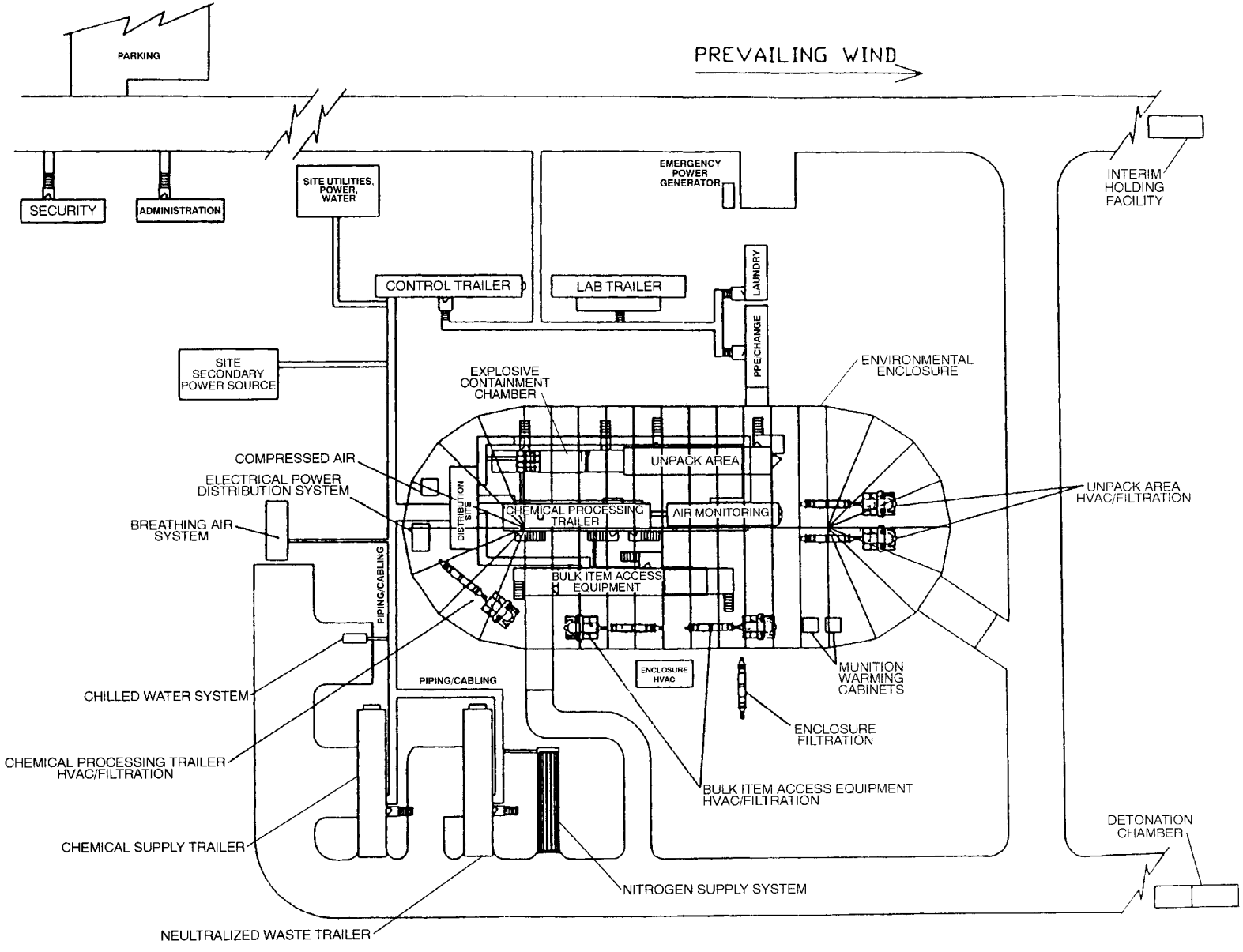


Figure C.4-1. Conceptual Site Plan for the Munitions Management Device - Version Two

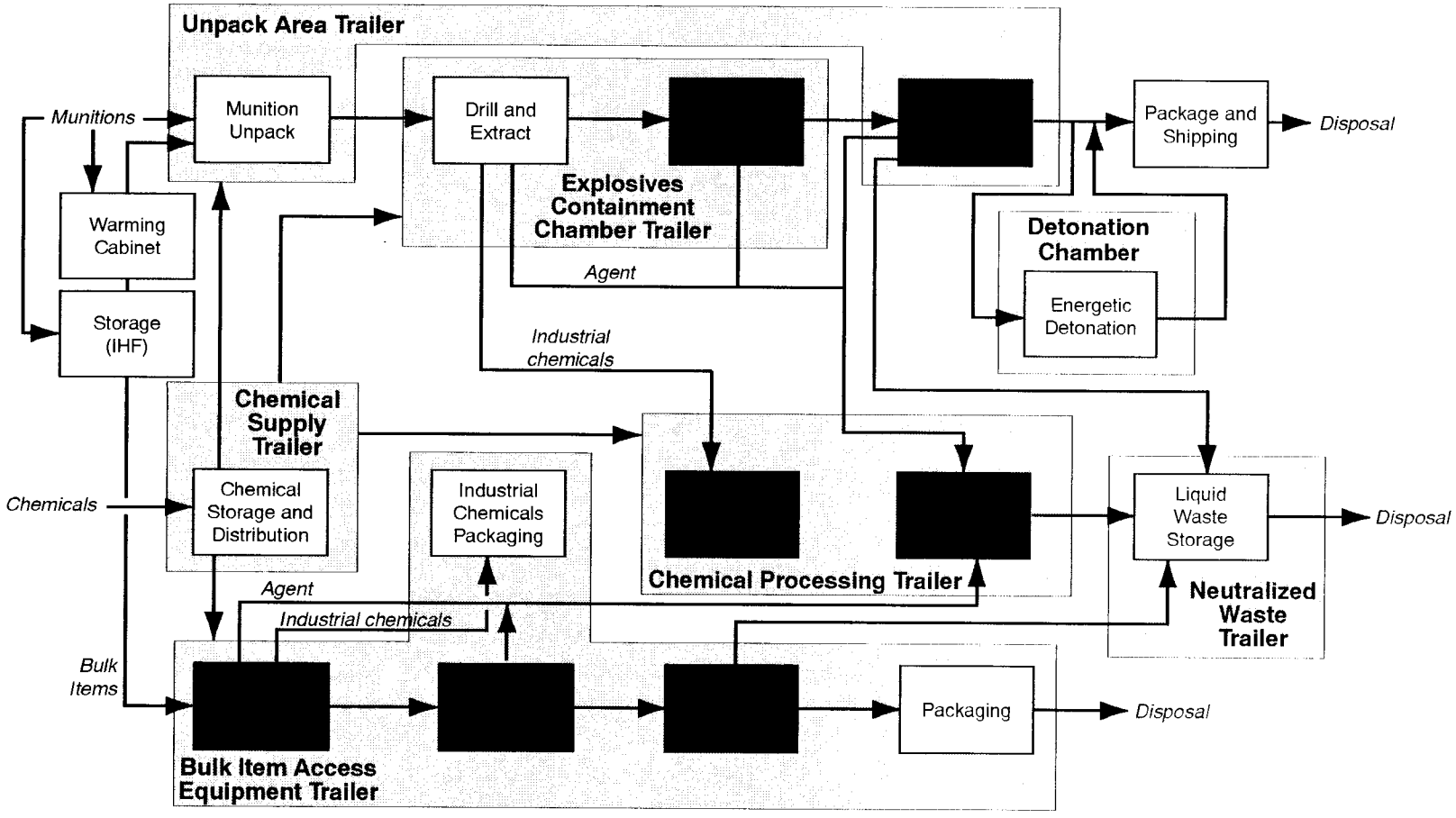


Figure C.4-2. Process Flow Diagram for the Munitions Management Device - Version Two

Once a munition is readied for processing, it would be transferred from the unpack area trailer to the explosive containment chamber (ECC) trailer. In the ECC trailer, the munition would be placed into an auxiliary process vessel. In the auxiliary processing vessel, the munition would be breached, a vapor sample taken and analyzed to confirm chemical fill, and chemical contents drained. Only one munition would be accessed at a time.

Chemical fills would be transferred by piping from the explosive containment chamber trailer to a reactor vessel in the chemical processing system trailer, where the chemical fill would be combined with an appropriate treatment reagent, or repackaged if the chemical fill is not to be treated.

Treatment reagents would be prepared in the chemical supply system trailer and pumped to a reactor in the chemical processing system trailer. The treatment reagents that would be used in the MMD-2 are the same as those discussed for the MMD-1.

The neutralent generated from the treatment reaction of a chemical fill with a treatment reagent would be sampled to determine treatment effectiveness and pumped from the reactor to a neutralent holding tank in the chemical processing trailer, where the neutralent would temporarily be held pending the result of the analyses for treatment effectiveness. Once treatment effectiveness has been confirmed, the neutralent would be transferred to the neutralized waste system trailer where the neutralent would be collected, sampled, and either packaged into intermediate bulk containers for temporary waste storage or unloaded into a hazardous waste tanker truck.

The drained munition with intact explosive components would be returned to the unpack area for decontamination and monitoring to determine the level of decontamination. Spent decontamination solutions generated from decontaminating the drained munitions would be pumped to a neutralent holding tank in the chemical processing system trailer, where the solutions would be sampled and analyzed.

After the munition has been decontaminated, the munition with intact explosive components would be taken to the detonation chamber trailer where it would be detonated. Metal parts, fragments, and explosive residue would be collected, containerized, characterized, and temporarily stored pending further treatment, as required, and ultimate disposition.

Non-stockpile munitions without explosive components and containers of chemical agent that could be processed in the MMD-2, would be processed similar to munitions with explosive components, except that munitions without explosive components and containers would not be taken to the detonation chamber trailer for detonation. Instead, they would be processed in the unpack area, similar to the processing of decontaminated munition casings and containers described for the MMD-1, and transported off site for final disposition (which in most cases would be recycling). Waste from the processing of the decontaminated

munition casings and containers would be collected in containers meeting USDOT specifications and held pending ultimate disposition.

Bulk items would treated inside the bulk item accessing equipment trailer instead of in the unpack area and the ECC trailers. The bulk items would be penetrated and the agent would be drained and sent to the chemical processing trailer. When the bulk item is fully drained, it would be flushed with neutralizing fluid (triple rinse) and then flushed with water. The bulk item would then be sectioned and the eductor and valve hardware would be removed and decontaminated, if applicable. Any sections that contain scale would be decontaminated by dry ice blasting. The resulting metal parts would be sent to a waste storage area pending ultimate disposition. The bulk item accessing equipment trailer would also repackage industrial chemicals in bulk items, such as phosgene.

C.4.2 Components of the Munitions Management Device — Version Two

The following subsections describe the major treatment components and systems of the MMD-2.

C.4.2.1 Unpack Area Trailer

The purpose of the MMD-2 unpack area (see Figures C.4-3 and C.4-4) is to provide a contained area for operations required to process the overpacked munitions as part of the overall program. These operations include the following: opening of the overpack and munition removal, decontamination of the overpack and munition agent neutralization and transfer to the chemical processing trailer, media blasting to remove agent residue, munition leak repair, munition placement into the auxiliary processing vessel cradle, washing, inspection (visual and X-ray), component trimming and removal, vacuuming, drying, testing, and repackaging.

The MMD-2 unpack area would consist of a single enclosed trailer separated into two rooms with a separate enclosure connection to the ECC trailer (see Figure C.4-5).

The process room would house equipment required to perform munition unpack, prepare the munition for drill and extraction, munition post-extraction cleaning, testing for cleanliness, and final demilitarization of explosively configured munitions. Additionally, the process room would also house the equipment and systems to process (including decontamination of the packing material and containers) the overpacks and/or single round container.

The airlock room would provide for entrance and egress of personnel, munitions, and support equipment. Additionally, the airlock room would provide the ability to perform initial decontamination of personnel in level 'A' PPE before egress from the trailer. Storage of incoming overpacks from the munition warming cabinet and outgoing munitions would be provided in the airlock room as well.

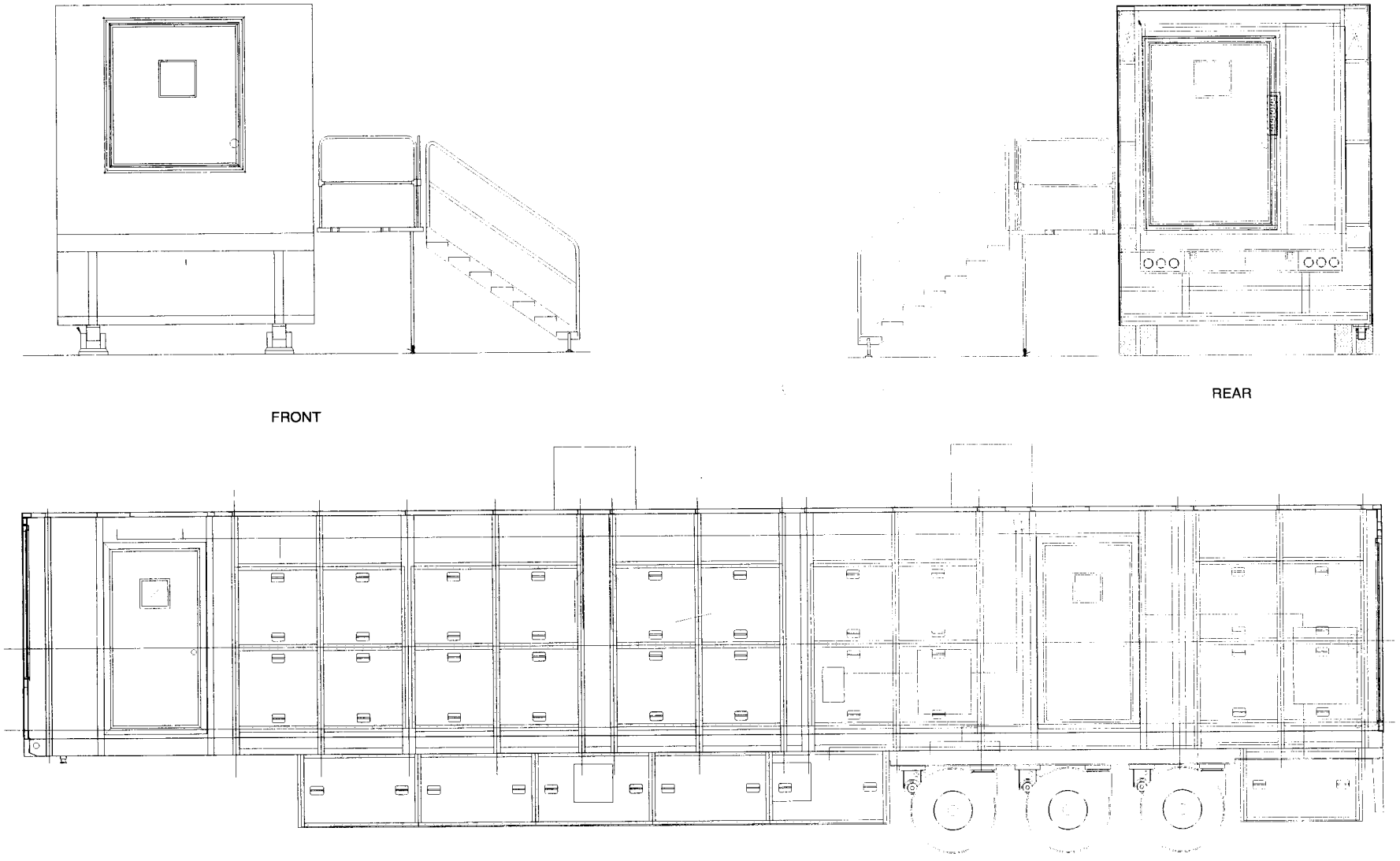


Figure C.4-3. Exterior of the Unpack Area Trailer

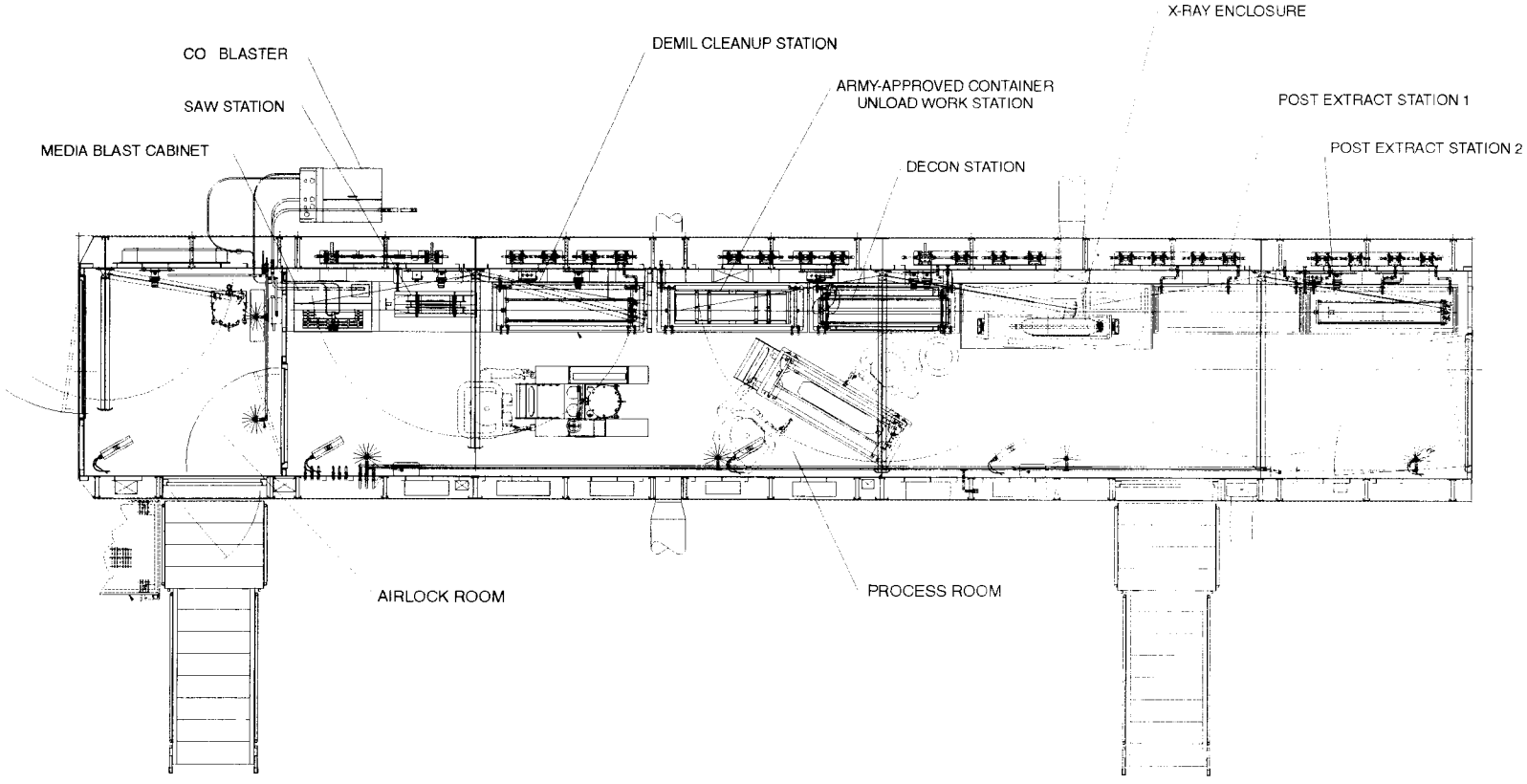


Figure C.4-4. Unpack Area Trailer

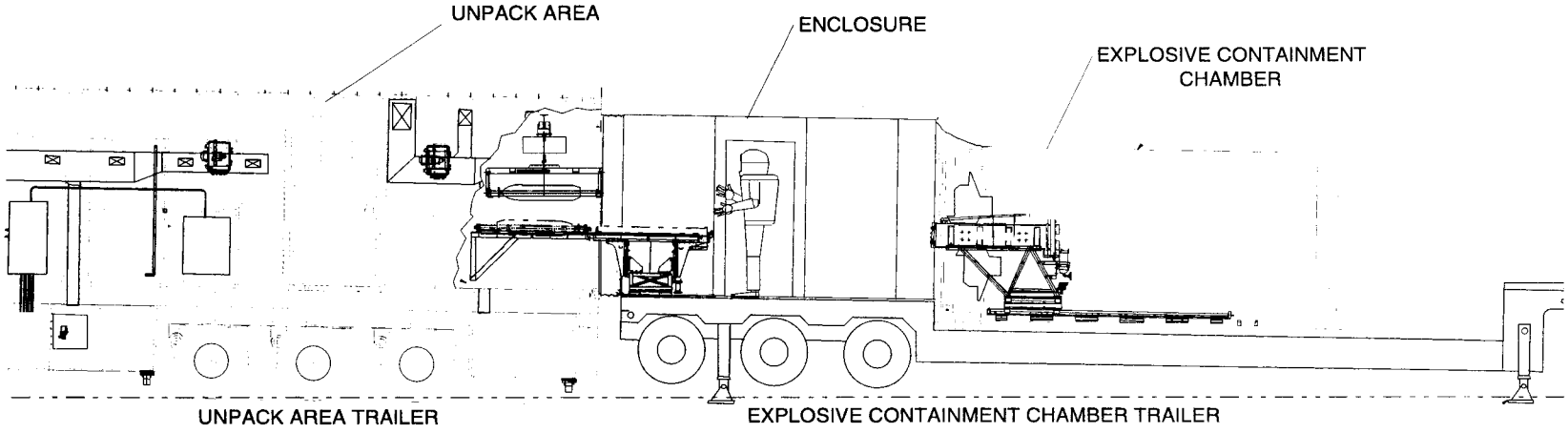


Figure C.4-5. Connection of the Unpack Area Trailer to theExplosive Containment Chamber

The unpack area trailer would be connected to the ECC trailer. An enclosed area on the ECC trailer would connect the unpack area with the ECC (see Figure C.4-5).

C.4.2.2 Explosive Containment Chamber Trailer

The ECC trailer (see Figure C.4-6) performs the drill and extraction function for demilitarization of chemical filled munitions. This system utilizes a drill and extraction system installed inside a cylindrical ECC to safely remove the internal chemical fills while providing multiple levels of containment.

The MMD-2 ECC trailer has four major components—the ECC, the explosive chamber interface containment (ECIC) room, the auxiliary processing vessel (APV), and the drill and extraction system—providing for the capability to safely extract the internal chemicals from hazardous munitions while ensuring vapor containment at all times. The ECC is a horizontally configured, cylindrical containment chamber developed and tested by Bofors-Dynasafe (see Figure C.4-7). Extending from the back of the ECC is the ECIC, which provides a second level of containment for the valves, piping, and cables exiting the ECC. Inside the ECC is the APV, which contains the chemical munition during the drill and extraction process, providing an additional level of vapor containment. There are also two drill and extraction units sealed to the APV, one on the top and one on the bottom that provides the capability to drain the chemicals and circulate neutralization fluid through the munition casing.

C.4.2.3 Chemical Processing Trailer

The chemical processing trailer (see Figure C.4-8) houses the equipment required for liquid agent neutralization and industrial gas recontainerization (munition only) and contains the necessary engineering controls, air monitoring, and decontamination features whereby agent neutralization operations can be accomplished in a manner that is protective to the public and the environment. The chemical processing trailer receives undiluted liquid agent from the ECC trailer and the bulk item trailer. Agent neutralization would be accomplished in the liquid phase within agitated reactors using chemical neutralizing solutions from the chemical supply system trailer. The chemical processing trailer consists of a process room, a panel room, and an entry room.

The process room contains the chemical process equipment and piping for chemical neutralization and recontainerization. The process room is operated at a nominal pressure of 0.5 inches of water less than the pressure of the environmental enclosure. An exterior duct provides an umbilical connection between the process room and the ECC. A second duct connects the process room with the bulk item access equipment trailer. The ducts provide an additional level of containment for the agent and other lines that run between the process room and other trailers.

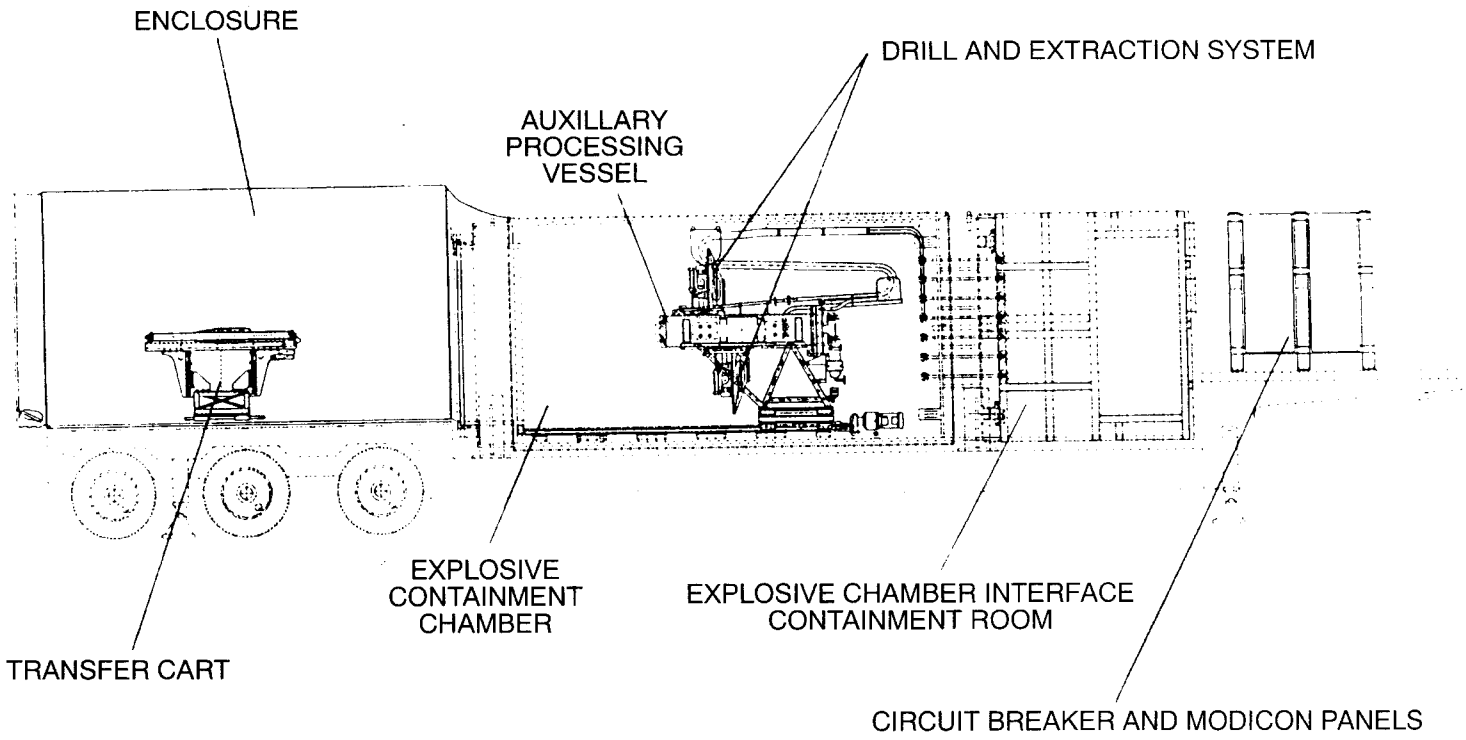


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Figure C.4-6. Explosive Containment Chamber Trailer

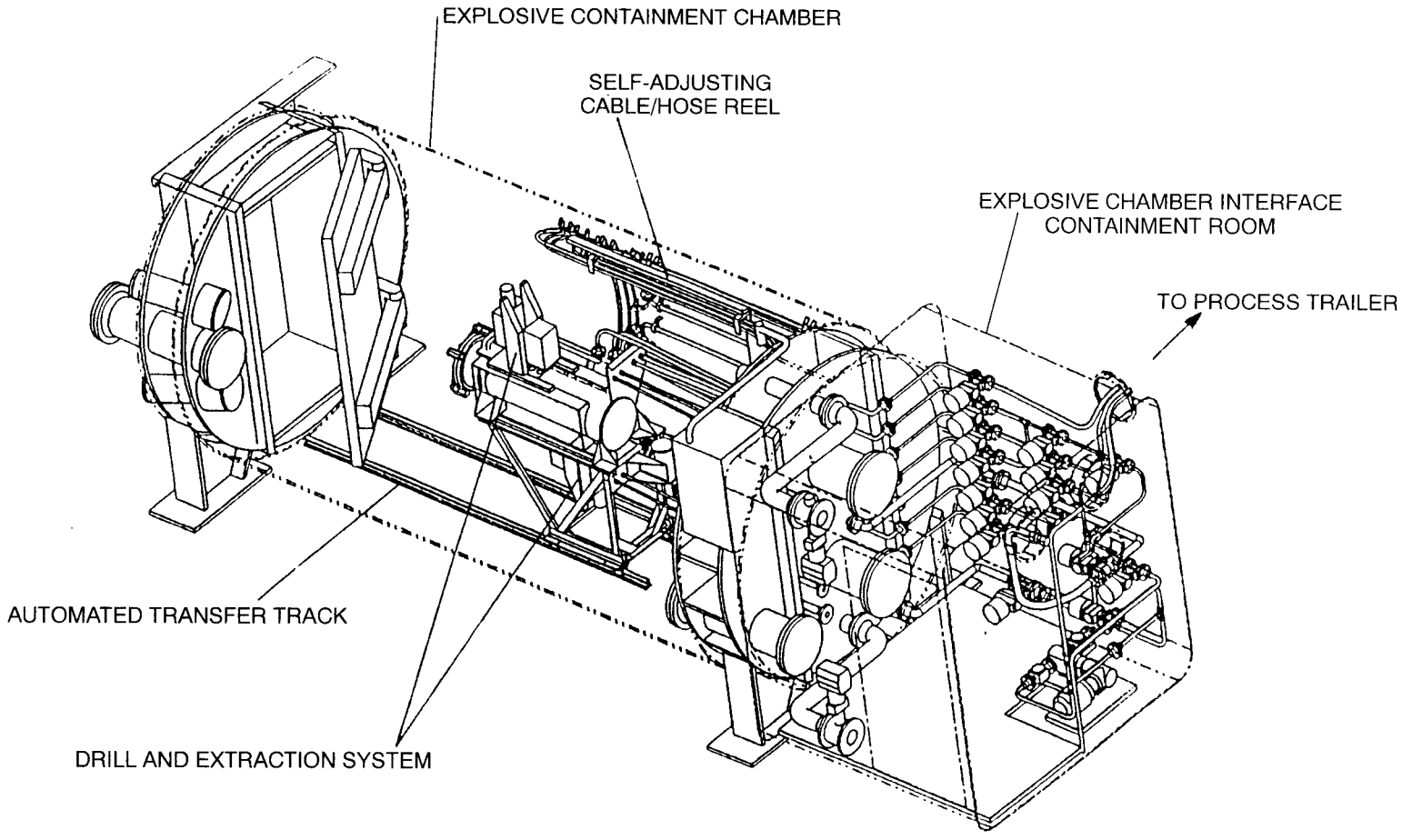

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Figure C.4-7. Explosive Containment Chamber

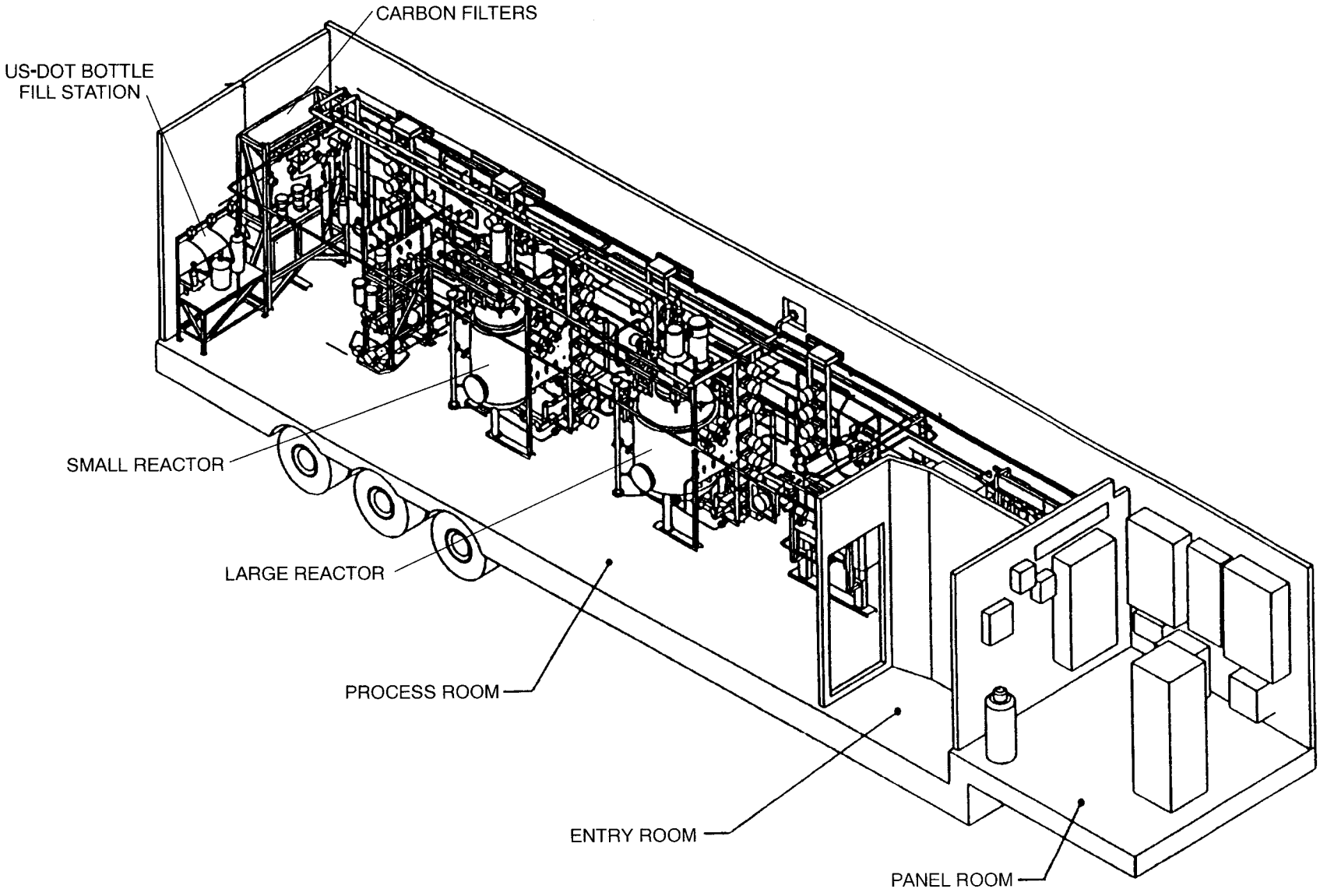


Figure C.4-8. Chemical Processing Trailer

The panel room provides a temperature-controlled area to house electrical equipment, control equipment, and pneumatic panels. The panel room operates at the same pressure as the environmental enclosure.

The entry room is used to decontaminate personnel clad in level 'A' PPE if agent is detected prior to exiting. An independent sump drain is provided for the entry room. Leakage is piped to the process room through a check valve, which prevents process room leakage from flowing into the entry room.

C.4.2.4 Chemical Supply System Trailer

The chemical supply system (see Figure C.4-9) would temporarily store and deliver reagents, chemicals, and process water in support of agent neutralization activities. The chemical supply system would be contained in a temperature-controlled, fully enclosed, road-ready mobile trailer. Each reagent and chemical would be loaded on site after setup is completed at a treatment site. Similarly, all remaining reagents and chemicals stored in the trailer would be removed prior to transportation from the site. The trailer consists of two areas; the chemical storage area and the chemical supply area.

The chemical storage area receives and safely stores reagent chemicals from the contracted chemical supplier. The chemical supplier would furnish pre-mixed concentrations in 350-gallon (1,325-liter) stainless steel U.S. Department of Transportation and United Nations certified bulk containers delivered on an as-need basis. The chemical storage area is capable of storing 1,400 gallon (5,300-liter) of reagent in four 350-gallon (1,325-liter) containers. In addition to the primary storage, 1,400 gallon (5,300-liter) of auxiliary chemical storage would be provided along the roadside of the trailer in four 350-gallon (1,325-liter) containers.

The primary function of the chemical supply system would be to distribute process water, reagent for neutralization, and chemical for decontamination to the Environmental Enclosure at a flow rate and pressure sufficient to support all agent neutralization activities. The chemical supply system contains three 350-gallon (1,325-liter) containers that could be filled with any one of three different reagents depending on the current campaign.

C.4.2.5 Neutralized Waste System Trailer

The neutralized waste system trailer (see Figure C.4-10) would temporarily store the liquid wastes generated from treating chemical fills and from decontaminating items. The system consists of several stainless steel tanks that would be equipped with agitators and one large tank for aqueous waste associated with decontaminating and rinsing operations.

Neutralent wastes and spent decontamination solutions from treatment and decontamination activities would be transferred from the chemical processing system trailer, ECC trailer, and bulk item accessing equipment trailer to the neutralized waste system trailer. Wastes are collected, segregated, and containerized in this trailer. When sufficient volume has been accumulated waste containers are transferred to the temporary waste storage area

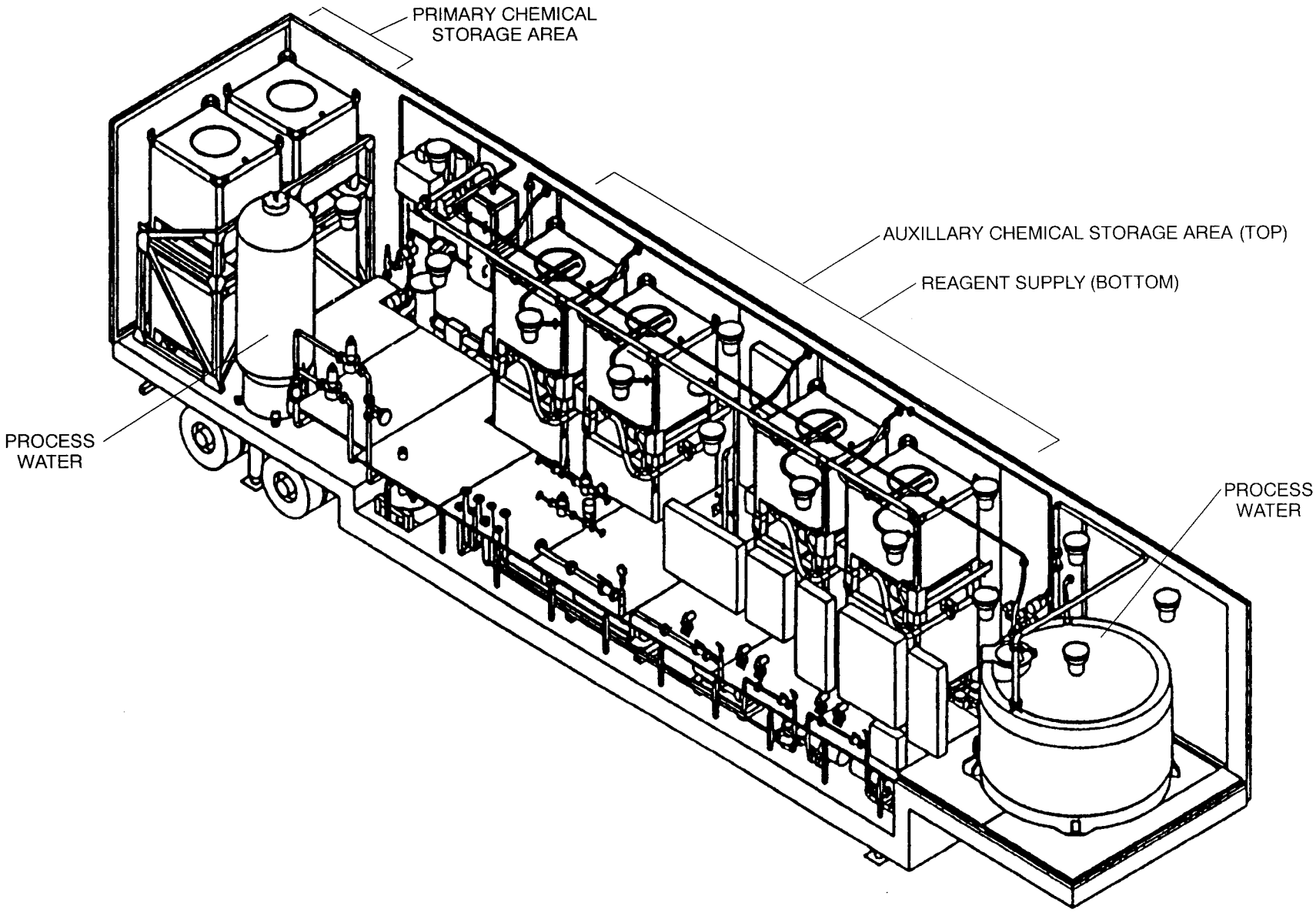


Figure C.4-9. Chemical Supply System Trailer

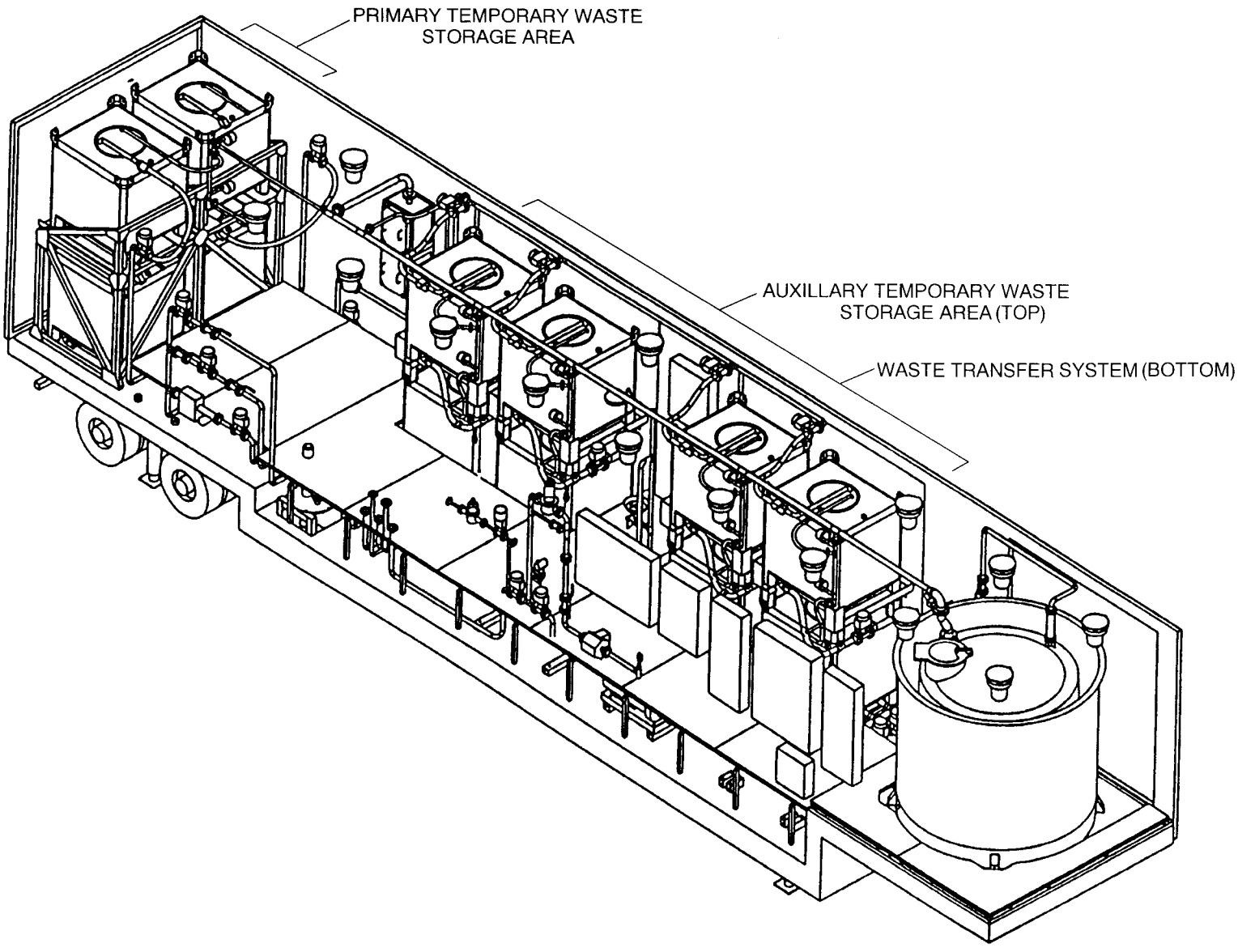


Figure C.4-10. Neutralized Waste System Trailer

for temporary storage. The system also could transfer wastes directly to a hazardous waste tank truck. All wastes would be sampled before leaving the neutralized waste system.

C.4.2.6 Bulk Item Accessing Equipment Trailer

The bulk item accessing equipment trailer (see Figures C.4-11 and C.4-12) is used to access, decontaminate, and transfer the contents of bulk items too large to be processed in the explosive containment chamber. Bulk items would not be explosively configured. The major components of the system would include drilling and cutting equipment, transfer lines, bulk item handling equipment, and decontamination equipment that includes a carbon dioxide pellet system (dry ice blasting). The bulk item accessing system would be supported by an air filtration system. The system would be trailer mounted.

Bulk items would be prepared as necessary and loaded onto a transport cart for processing in the pressure vessel room of the bulk item accessing system trailer. Only one bulk item would be processed at a time. In the pressure vessel room, the bulk item would be breached and the vapor sampled to confirm the chemical fill. A chemical fill to be treated would be transferred to the reactor vessel in the chemical processing systems trailer where the chemical fill would be reacted with the appropriate treatment reagent. Chemical fills from very large bulk items would require several batch reaction runs to treat all of the fill.

After the contents of a bulk item are removed, the bulk container would be decontaminated by triple rinsing the item with an appropriate reagent. The decontamination solution would be pumped to the chemical processing system trailer for sampling and analysis and treatment, if required. The bulk item container would then be sectioned into pieces, as necessary, and the sectioned pieces further cleaned with a carbon dioxide pellet system. Decontaminated bulk item containers and metal parts would be monitored to ensure decontamination prior to temporary storage and ultimate disposition.

Bulk shipping and storage containers with chemical fills that would not be treated would only be processed in the bulk item accessing trailer if the container was not in satisfactory condition for transport. If bulk item containers were not in satisfactory condition, the chemical fills would be accessed in the bulk item accessing equipment trailer and repackaged into appropriate containers.

C.4.2.7 Detonation Chamber Trailer

Decontaminated, drained CWM munitions with explosive components would be detonated in the detonation chamber trailer (see Figure C.4-13). All fragments and gases resulting from the detonation of items would be contained in the detonation chamber, and the chamber would be vented after detonation through a charcoal filtration system. The metal fragments and energetic residue generated from intentional detonation would be collected, containerized, appropriately characterized, and temporarily stored pending ultimate disposition.

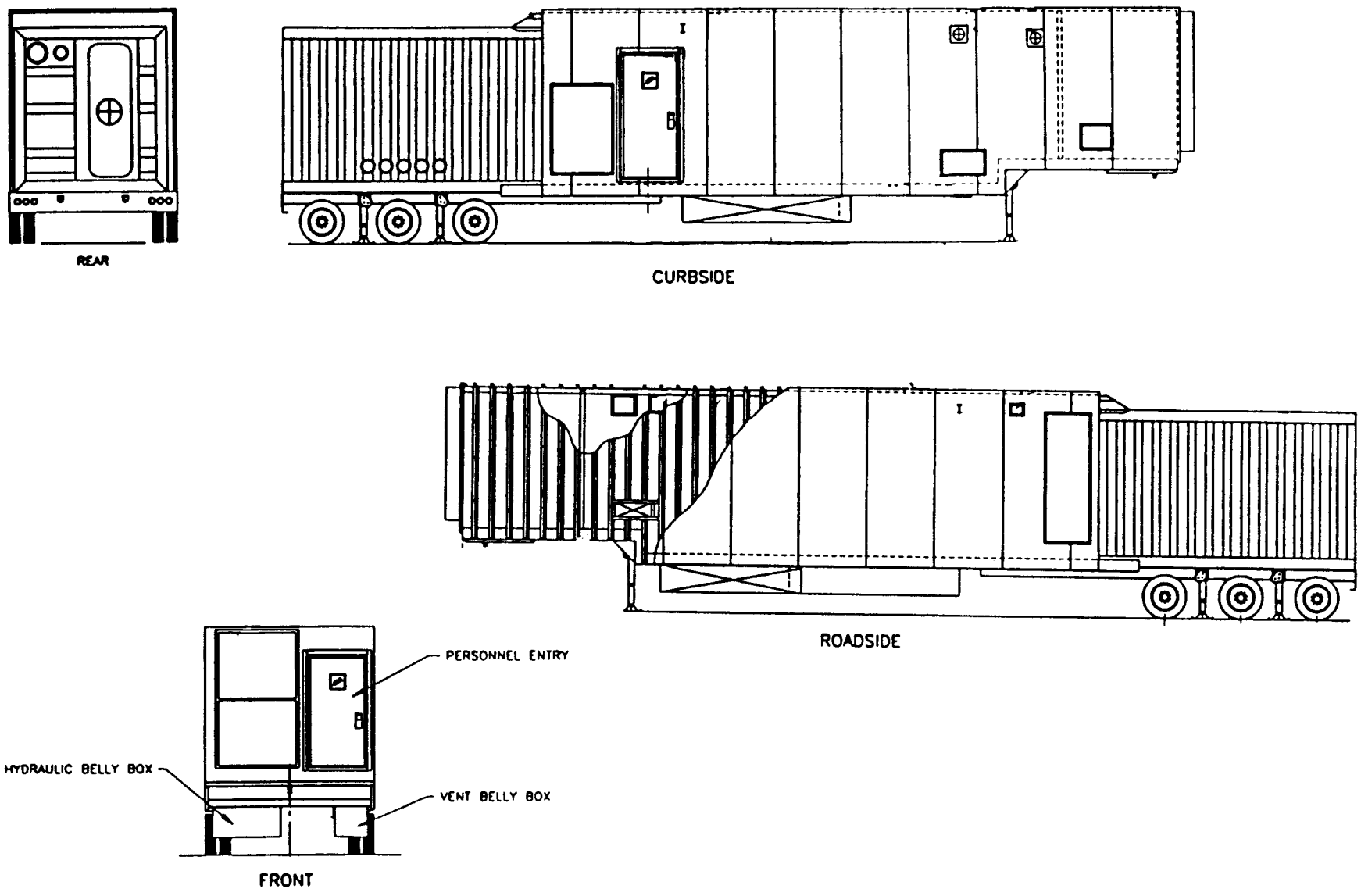


Figure C.4-11. Exterior of the Bulk Item Accessing Equipment Trailer

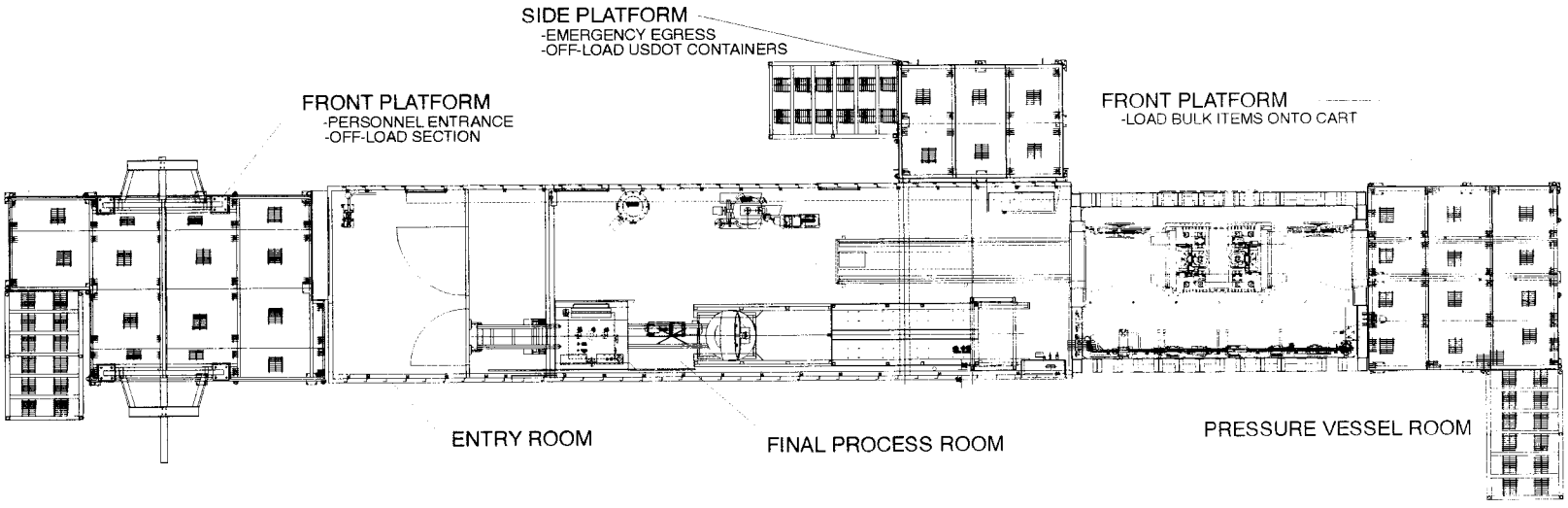
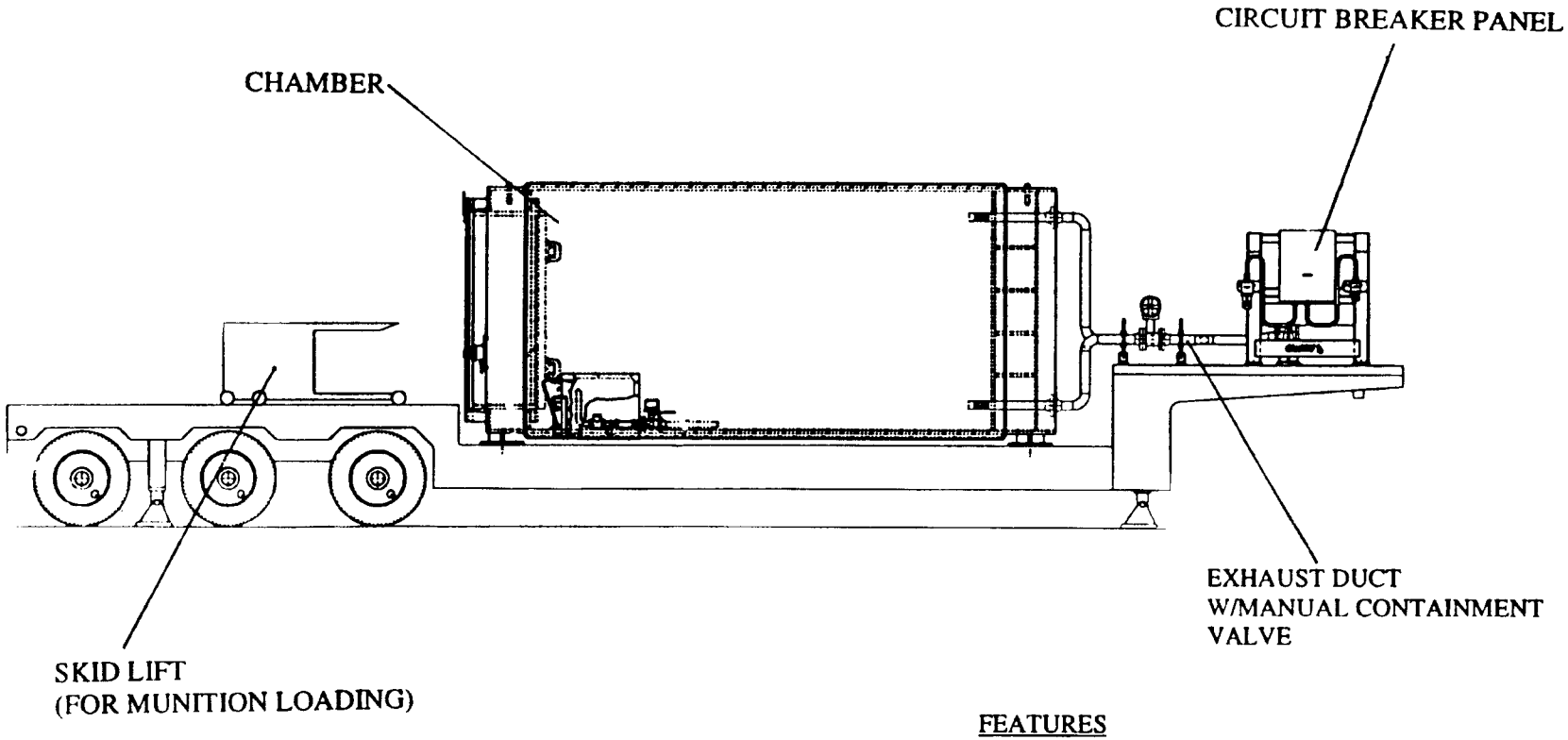


Figure C.4-12. Bulk Item Accessing Equipment Trailer



FEATURES

- CHAMBER SIMILAR TO ECC W/ADDITIONAL FRAGMENTATION CONTAINMENT
- MANUAL CONTAINMENT VALVES W/POSITION INDICATORS
- SEPARATE VENTILATION AND FILTRATION SKID

Figure C.4-13. Detonation Chamber Trailer

C.4.2.8 Control Trailer

All chemical materiel accessing and treatment operations in the MMD-2 would be controlled from the control trailer (see Figures C.4-14). The trailer would contain the distributed control system, electrical power distribution equipment, communications equipment, and an uninterruptible power supply system. The control trailer would be located outside of the environmental enclosure.

C.4.2.9 Utility and Support Systems

Several utility and support systems are associated with the MMD-2. The systems include a munition warming cabinet, an emergency power generator, an instrument air compressor, a chilled water system, a breathing air system, a nitrogen supply trailer, a PPE change-out trailer, and a distribution skid (see Figure C.4-1). These systems are being designed for outdoor operation and for transport.

Munitions warming cabinet. This system raises the temperature of munitions prior to entry into the unpack area trailer. Because laboratory grade mustard agent becomes solid at approximately 59°F (15°C), the cabinets would provide a means of raising the temperature of mustard-filled munitions to facilitate agent extraction and neutralization. The cabinet is capable of heating the chemical agents in four overpacked munitions from a temperature of about 39°F to 75°F (4°C to 24°C) in a 72-hour period.

Emergency power generator. The generator supplements the uninterruptible power supply system to accomplish the safe shutdown of the MMD-2 upon loss of primary electrical power. The system is skid-mounted.

Instrument air compressor. This compressor provides instrument air to a number of the components of the MMD-2. The system is skid-mounted.

Chilled water system. This system provides the chilled water capacity required for heat removal in the chemical reactor system, which is located within the chemical processing system, and for the HVAC systems. The system is skid-mounted.

Breathing air system. This system provides low-pressure air to personnel air supply manifolds and high-pressure air to an air bottle refilling station. Air supply manifolds would be located in the chemical processing system trailer, unpack area trailer, and the explosive containment chamber trailer. The bottle refilling station would be located outside the environmental enclosure. The system is skid-mounted.

Nitrogen supply trailer. The trailer provides nitrogen necessary for MMD-2 operations. The nitrogen would also be used for blanketing process vessels to prevent potentially flammable vapor contents from becoming a fire hazard.

Personal protective equipment change-out trailer. The trailer is for the donning and doffing of PPE and for showering. The personnel decontamination line would extend from the end of the change-out trailer to the environmental enclosure.

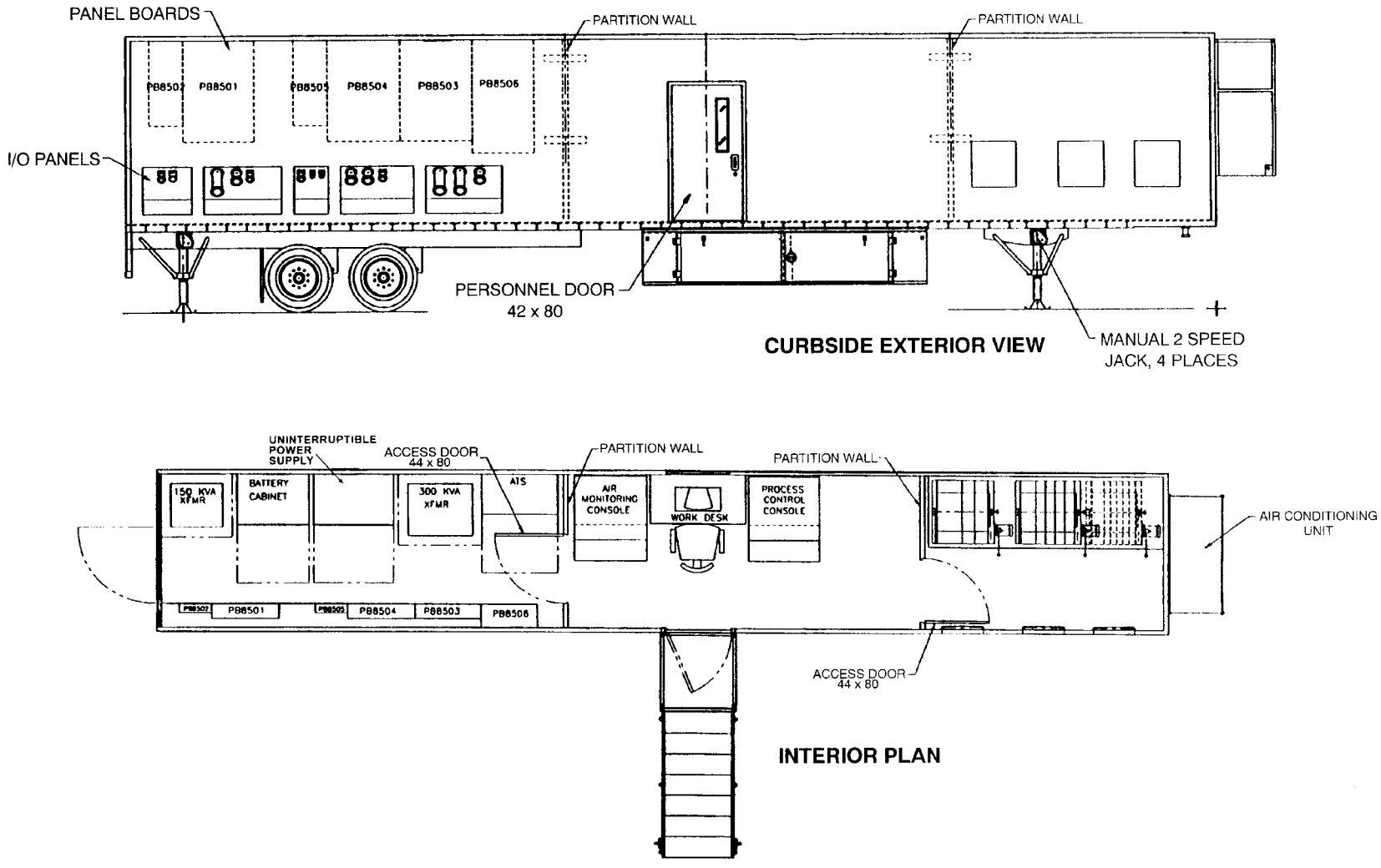


Figure C.4-14. Control Trailer

Distribution skid. The skid disburses all non-electrical utilities from supply and support systems located outside the environmental enclosure to the systems inside the environmental enclosure. Also contains the reagent heating systems and the chemical processing trailer booster chiller. The reagent heating system would elevate the temperature of a single treatment reagent to 129°F (54°C) before treatment, and the booster chiller would remove heat generated during treatment activities.

C.4.2.10 Environmental Enclosure

An environmental enclosure would always be used in conjunction with the MMD-2 (see Figure 4.C-15). The main purpose of the environmental enclosure would be to provide a moderate working environment around the processing systems and to reduce the heating and cooling requirements for the trailers located inside the enclosure. The enclosure would also provide an additional level of vapor containment between those MMD-2 components having the potential for internal chemical materiel contamination and the ambient environment.

The environmental enclosure would house the chemical processing system trailer, the unpack area trailer and munition warming cabinet, the air monitoring systems, the distribution skid, and the bulk item accessing and ECC trailers when deployed with the MMD-2 (see Figure 4.C-1). The environmental enclosure would be constructed of flexible walls over a rigid framework and would include a portable ground cover liner. The estimated size of the enclosure would be approximately 197 feet (60 meters) long by 89 feet (27 meters) wide. Interlocking pierced steel planking would be placed in the structure for concentrated load areas (for example, the operations trailer) and an expanded metal mat floor surface placed where forklifts or other vehicles would travel inside the enclosure. Footings and appropriate curbing would be poured, if required. The enclosure would have a heating, ventilating, and air conditioning system to provide heating, cooling, and humidity control.

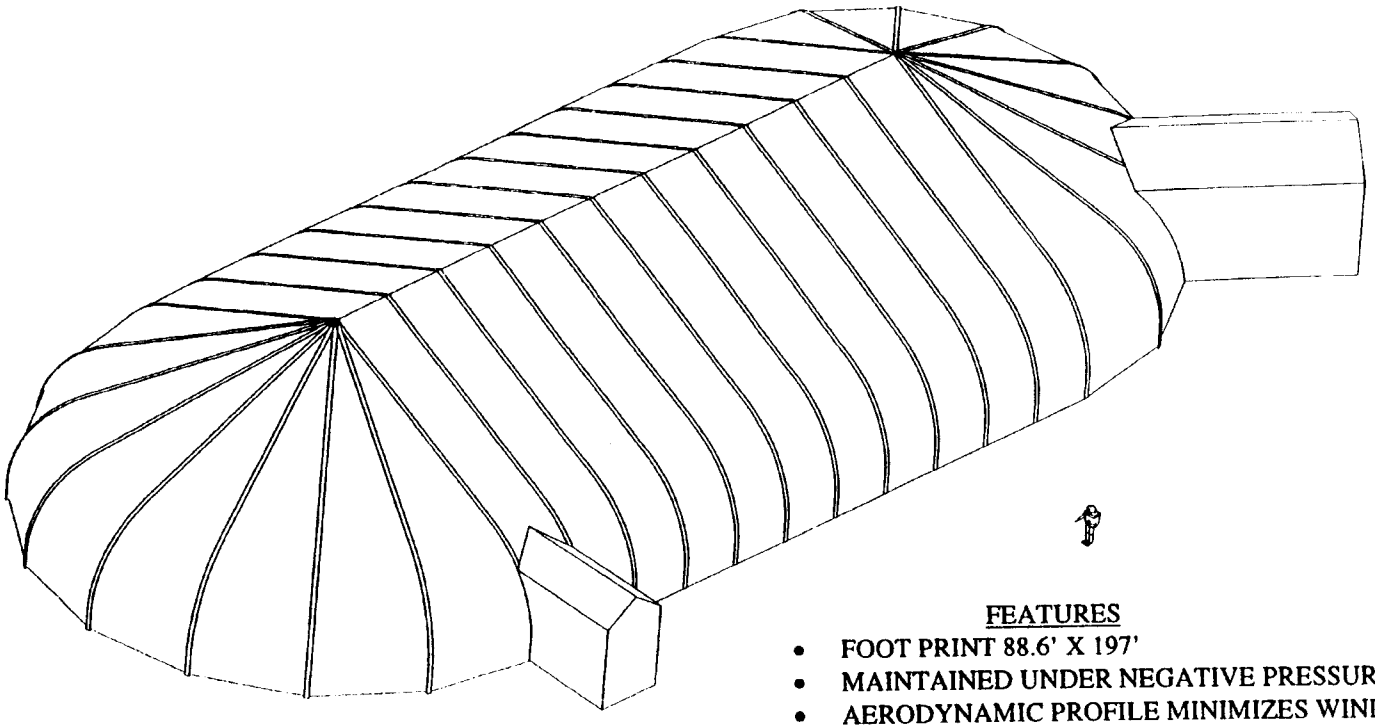
Inside air would be released to the ambient environment through a charcoal-type filtration system. The filtration system would have the capability to connect to the operations trailer exhaust port.

Panels built into the walls of the enclosure would allow for penetrations of electrical and other support service lines. A forklift battery charging station would also be contained in the environmental enclosure.

An airlock would provide for entrance and egress of personnel. Within the airlock, sufficient space would be provided for personnel to change into and out of PPE, and a shower would be available for decontaminating the exterior of PPE. A second airlock would be provided to accommodate the movement of vehicles and equipment into and out of the enclosure.

C.4.2.11 Other Support Facilities

Other facilities also may be required at a site to support site operations depending on facilities already available at the location. These other facilities include an interim holding



FEATURES

- FOOT PRINT 88.6' X 197'
- MAINTAINED UNDER NEGATIVE PRESSURE
- AERODYNAMIC PROFILE MINIMIZES WIND AND SNOW LOADS
- EXTERNALLY LOCATED HVAC SYSTEM W/ AIR MONITORING
- INSULATED
- EXTERNALLY LOCATED CHARCOAL BASED FILTRATION SYSTEM
- INTERNAL LIGHTING W/ SKYLIGHTS
- 2 VEHICLE ENTRANCES
- PERSONEL ENTRANCE
- 3 EMERGENCY EXITS
- MUST CONFORM TO LOCAL BUILDING CODES, ASCE, AND ANSI STANDARDS

Figure C.4-15. Environmental Enclosure

facility, a temporary waste storage area, an administrative trailer, a laundry room, a security trailer, and a site secondary power source.

C.4.3 Treatment Chemistry

The details of the treatment chemistry are still under development. However, the processes would use the same reagents as the MMD-1, and the treatment processes would be similar. The treatment chemistry of the MMD-1 is described in Section C.3.3.

C.4.4 Wastes and Emissions

The following subsections discuss the expected wastes and air emissions that would be generated from MMD-2 processing and treatment operations. During normal operation of the MMD-2, no liquid effluents would be generated that would be discharged to surface or groundwater, except for operational personnel sanitary waste for which either existing sanitary systems or portable facilities would be used.

C.4.4.1 Wastes

The composition of neutralent wastes from treating chemicals have not yet been determined. These wastes are likely to be similar to those from the MMD-1, as listed in Table C.3-1, except that explosive resolve would be present. Other wastes would be generated from MMD-2 treatment operations. These include (1) the spent reagent (neutralents) generated from treatment of chemical fills, (2) decontaminated packing materials, metal containers, and munition casings, (3) uncontaminated packaging materials, (4) spent decontamination solutions and rinse waters, (5) spent carbon and filter elements, (6) recontainerized industrial chemicals from industrial chemical fills not treated in the MMD-1, (7) spent cleanup materials, trash, and debris, (8) used PPE, (9) spent hydraulic fluid, (10) spent coolant/chiller fluids, and (11) residue from dry ice blasting. Table C.4-1 lists the wastes that would be generated during MMD-2 operations, the activity or process that would generate each waste, and the physical state of each waste.

C.4.4.2 Emissions

The potential source of emissions from MMD-2 operations include those (1) from the operation of diesel generators for electrical power supply; (2) from the unpack area, chemical processing system, and bulk item accessing equipment trailers to within the environmental enclosure, (3) from the environmental enclosure, and (4) from the detonation chamber.

Diesel Generators. An emergency standby diesel-powered generator would be used to complete a treatment process in the MMD-2 or to safely shutdown MMD-2 operations in the event of a loss of primary power. Periodic maintenance of the diesel-powered generator would be performed to sustain efficient operation. The emergency diesel generator is currently estimated as having to provide approximately 500 kilowatts of electrical power. As currently designed, the MMD-2 would require about 1,335 kilowatts of electrical power during normal operation that would be provided by a local electrical power supply system. If a source of local electrical power supply is unavailable, a generating system would be required at the

Table C.4-1. Waste Steams from the Munitions Management Device–Version Two

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Neutralents	Chemical treatment of chemical agent fills	Liquid[b]	Permitted commercial hazardous waste treatment, storage, and disposal facility (TSDF).
Neutralents	Chemical treatment of phosgene fills	Liquid	Permitted commercial hazardous waste TSDF.
Repackaged industrial chemicals	Draining and transferring industrial chemical fills from munitions and bulk items to appropriate shipping containers	Varies[c] (solid/liquid)	Permitted commercial hazardous waste TSDF.
Decontaminated overpacks, metal containers, munition casings, metal fragments, and metallic packing materials	Decontamination of chemical agent contaminated overpacks, metal containers, munition casings, metal fragments, and packing materials	Solid (may contain free liquids)	Recycling facility (Rock Island Arsenal or similar DoD facility). Otherwise, permitted commercial hazardous waste TSDF.
Decontaminated non-metallic packing materials	Decontamination of non-metal packing materials contaminated by agent	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Non-agent contaminated metal containers and munition casings	Processing of munition casings and containers with industrial chemical fills (following draining of the fill)	Solid	Recycling facility (Rock Island Arsenal or similar DoD facility). Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated overpacks	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid (may contain free liquids)	Cleaned and reused. Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated packing materials	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Uncontaminated overpacks	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Reuse.

Table C.4-1. (Continued)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Uncontaminated packing materials	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Permitted solid waste landfill.
Spent decontamination solutions and rinse waters	Decontamination, cleaning, and rinsing operations (including emergency personnel decontamination station)	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Bead blast residue	Abrasive cleaning and descaling of decontaminated metal munitions bodies and parts from munitions with chemical agent fills	Solid	Permitted commercial hazardous waste TSDF.
Bead blast residue	Abrasive cleaning and descaling of decontaminated metal munitions bodies and parts from munitions with industrial chemical fills	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Energetic residues	Intentional detonation of decontaminated munition bodies with intact energetics	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Spent carbon and other filter elements	Change-out of filter elements from filtration units associated with the processing of chemical agent (for example, carbon filter unit system)	Solid	Permitted hazardous waste TSDF.
Other spent filters	Change-out and replacement of filter elements not associated with the processing of chemical agent	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Used personal protective equipment[e]	Personal protective equipment generated from treatment system operations	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.

Table C.4-1. (Concluded)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[d]
Laboratory wastes	Laboratory activities (for example, analysis, calibration, maintenance, and cleaning); spent chemicals and materials	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.
Spent cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
HVAC condensate	Use of HVAC systems	Liquid	Tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in containers for subsequent treatment at an existing wastewater treatment facility.
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Includes wastes from the pre-operational survey.

[b] The neutralent waste generated would be dependent upon the chemical agent fills of the chemical munitions to be treated at each site location.

[c] The physical state would vary depending on the industrial chemical present.

[d] Wastes would be tested for the presence of chemical agent. If present, the waste would be decontaminated and, except for decontaminated overpacks, metal containers, munition casings, etc., would be sent to a permitted commercial hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

[e] Single-use PPE would be disposed. Multi-use (reusable) PPE might be cleaned and reused rather than disposed. This would be a site-specific decision based on such factors as practicality, cost-effectiveness, integrity of the item, and availability of laundry facilities.

HVAC Heating, ventilating, and air conditioning
TSDF Treatment, storage and disposal facility

treatment site. The emergency standby diesel-powered generator and a generator for normal power, if required, would discharge engine combustion gases and particulate matter.

Unpack Area, Chemical Processing Systems, and Bulk Item Accessing Equipment Trailer. These components of the MMD-2 would unpack, access, and treat or repackage the chemical fills in munitions and containers. Carbon filtration systems designed with separate elements and backup filter elements would be used to capture the specific chemical fills that would be handled in these components of the MMD-2. These redundant filters coupled with the near–real-time monitoring between the filter elements would be used to control and limit the potential release of hazardous concentrations of chemical agent and chemicals to within the environmental enclosure.

Environmental Enclosure. The components of the MMD-2 system that have the potential for internal chemical materiel contamination would be located in an environmental enclosure. The enclosure would provide an additional measure of vapor containment in the event of a spill or accidental release during handling or processing of chemical materiel. The environmental enclosure would have its own air filtration system and HVAC system to further control potential emissions to the atmosphere, including any vapors escaping from the MMD-2 components located within the enclosure.

Detonation Chamber. The detonation chamber is located outside of the environmental enclosure. A skid-mounted filtration system is used to remove potential airborne contaminants while monitoring for evidence of chemical contamination. This system utilizes a series arrangements of bag-in, bag-out filters consisting of a pre-filter, a high efficiency particulate air (HEPA) filter, two bag-in/bag-out charcoal filters, and a final HEPA filter in an enclosure that is maintained under negative pressure.

C.4.5 Monitoring Systems

Monitoring would be conducted to ensure the public and workers are protected. The monitoring systems for the MMD-2 comprise two types of air monitors: (1) near–real-time monitors and (2) confirmation and historical monitors. Monitors would sample at the locations listed in Table C.4-2.

C.4.5.1 Near–Real-Time Air Monitoring Systems

Multiple MINICAMS® would provide air monitoring during MMD-2 operations. The MINICAMS® would be configured to detect sulfur mustard, sarin, VX, phosgene, and other chemical agents and industrial chemicals that may be considered for treatment in the MMD-2 after prototype testing. The MINICAMS® would be the primary system used to warn MMD-1 operational personnel of a potential airborne exposure hazard. The MINICAMS® would be set to alarm when workplace ambient air concentration exceeds a specific level, at most 70 percent of the control limit (see Table C.4-3).

Table C.4-2. Air Sample Monitor Locations for the Munitions Management Device–Version Two

Sample Location	MINICAMS®[a]	Gross-Level MINICAMS®[a]	Depot Area Air Monitors[b]
Explosive containment chamber interior	X		X
Explosive containment chamber explosion chamber interface containment	X		X
Auxiliary processing vessel drill		X	
Explosive containment chamber entry way			X
Unpack area		X	
Unpack area near upender		X	
Unpack area at media blaster	X		
Unpack area at neutralization area	X		
Unpack area belly box 1			X
Unpack area belly box 2			X
Unpack area pipe chase			X
Unpack area airlock	X		X
Chemical processing trailer	X		X
Chemical processing trailer internal process filter midbed			X
Process trailer internal process filter exhaust			X
Chemical processing trailer entry room	X		X
Chemical processing trailer glovebox	X		X
Bulk item pressure vessel room	X		X
Bulk item pressure vessel room		X	
Bulk item final processing room		X	
Bulk item entry room	X		X
Bulk item decontamination/descale enclosure	X		
Bulk item carbon dioxide filter midbed			X
Bulk item carbon dioxide filter exhaust			X
Environmental enclosure (three locations)	X		X
Chemical processing trailer carbon filter midbed			X
Chemical processing trailer carbon filter exhaust			X
Bulk item accessing equipment carbon filter 1 midbed			X
Bulk item accessing equipment carbon filter 1 exhaust			X
Bulk item accessing equipment carbon filter 2 midbed			X
Bulk item accessing equipment carbon filter 2 exhaust			X
Unpack area carbon filter 1 midbed			X
Unpack area carbon filter 1 exhaust			X
Unpack area carbon filter 2 midbed			X
Unpack area carbon filter 2 exhaust			X
Environmental enclosure filter midbed			X
Environmental enclosure filter exhaust			X
Unpack area carbon dioxide filter midbed			X
Unpack area carbon dioxide filter exhaust			X
Detonation chamber			X
Detonation chamber midbed			X
Detonation chamber exhaust			X

a- near–real-time

b- historical

Table C.4-3. Control Limits for the Munitions Management Device-Version Two[a]

Chemical Materiel	Control Limits[e]	
	mg/m^{3}[b]	ppm/v[b]
Sulfur Mustard (HD)	0.003	0.00045[c,d]
Sarin (GB)	0.0001	0.00002[c,d]
VX	0.00001	0.0000009[c,d]
Phosgene	0.4	0.1[c]

[a] Workplace exposure level is an umbrella term encompassing all limits, including the 8-hour time-weighted average, the permissible exposure limit, the threshold limit value, and other levels developed to protect the worker during normal operations.
[b] Milligrams per cubic meter (mg/m^3) or parts per million by volume (ppm/v) at 20°C and 1 atmosphere.
[c] Value based on 8-hour time-weighted average.
[d] No individual will be intentionally exposed to direct skin or eye contact with any amount of solid or liquid agent, or to solid materials contaminated with chemical agent.
[e]. MINICAMS® would be set to alarm at a specific level that would not be more than 70 percent of the control limit.

Each of the MINICAMS® would have a different configuration, allowing simultaneous monitoring of various chemicals. The sarin and VX MINICAMS® would be configured with a flame photometric device with a specific band pass filter for phosphorus detection, while the sulfur mustard MINICAMS® would be configured with a photometric device with a specific band filter for sulfur detection. Phosgene would be analyzed with a MINICAMS® configured with a halogen selective detector to detect and quantify chlorine in phosgene's chemical structure. For VX monitoring, the VX is converted to a more detectable compound similar in chemical structure to sarin using a silver fluoride polyester conversion pad (that is, "V to G conversion pad") placed at the sample inlet of the heat traced sample line. The analog for VX and sarin both contain the phosphorous element used for flame photometric detection and therefore, can be assayed with the same MINICAMS®.

The MINICAMS® would automatically send a concentration report to a printer and floppy disk. The concentration report includes the date, time, instrument number, sampling port number, chemical materiel identity, summary, MINICAMS® operational mode, and the chromatographic information. At the end of each operational day, the concentration report would be collected from the printer and filed in the MMD-2 air monitoring files.

The MINICAMS® would also have the capability through an annunciator panel to activate a malfunction alarm if the system operates outside of parameter limits (flow, temperature, time, etc.) established by the operator.

C.4.5.2 Confirmation and Historical Monitoring Systems

Confirmation and historical air monitoring for MMD-2 operations would be conducted with depot area air monitor system (DAAMS) and colorimetric tubes. The DAAMS would perform two functions. First, the stations that would run collocated with the MINICAMS® would function as the primary confirmation means for the chemical agent MINICAMS®. Second, the stations would function as the primary means of chemical agent detection for quality control and historical analysis in situations where a MINICAMS® is not collocated (for example, at the filter exhausts). If a MINICAMS® is not being used as a primary monitor, DAAMS stations would be configured with duplicate sample tubes. Colorimetric tube collection ports would be located at each DAAMS station. The colorimetric tubes would be used and analyzed as a confirmation analysis in response to a phosgene MINICAMS® alarm.

C.4.6 Required Resources

Assembly of the MMD-2 trailer units and skid-mounted support equipment would require approximately 1.2 hectares (3 acres) of land. Setup of the MMD-2 trailer units and certain skid-mounted equipment would require a level surface. Approximately 40 personnel would be required for assembly of the system, which could take up to 2 months, and on average approximately 40 personnel would be required to conduct MMD-2 operations at a remote site. Crew members would be composed of engineers, scientists, and certified operators, including the following:

- MMD-2 Manager (chemical or environmental engineer)
- Site Safety Officer (environmental compliance and safety professional)
- Equipment Maintenance (mechanical, electrical, or hydraulics engineer)
- Logistics Manager (maintenance and supply experience)
- Command Post and Communications Operator (administrative and logistics experience)
- Control Room Operator (engineer)
- Laboratory Operators (chemist and laboratory technicians certified on MINICAMS®)
- Unexploded Ordnance Technicians (senior explosive ordnance disposal qualified personnel for unpack area operations)
- Monitoring Specialists (certified MINICAMS® operators)
- Chemical Technicians (chemical equipment operators, personnel decontamination station operators, waste handlers)

Engineers and technicians from the U.S. Army Ammunition Equipment Directorate and the Edgewood Chemical and Biological Center would be available to assist the MMD-2 crew, if required.

About 1,335 kilowatts would be required to operate the MMD-2. It is also estimated that approximately 4,000 gallons (15,140 liters) of water would be required per day for the following MMD-2 processes and activities: (1) treatment reagent preparation, (2) emergency personnel decontamination station operations, (3) cleaning and decontamination operations, (4) system closure operations, and (5) drinking water supply. Existing water supply systems would be utilized when available, and transportable potable water tanks would be used when an existing water supply system is not available rather than establishing a new water supply system. Existing sanitary facilities would also be used when available, and transportable sanitary facilities would be used when existing sanitary facilities are not available.

C.5 Explosive Destruction System

The Explosive Destruction System (EDS) is being developed to destroy non-stockpile CWM items determined not to be safe for routine handling and transport. The EDS could also be deployed, rather than the MMD-1 or MMD-2 systems, to treat safe explosively and non-explosively configured non-stockpile munitions (Sandia National Laboratories, 1996; Sandia National Laboratories, 1997). There are four key characteristics needed in the design of the EDS:

- Readily deployable to a wide variety of sites, including sites that are difficult to reach
- Able to handle and treat a variety of World War I- and World War II-era munition types with a variety of chemical fills
- Capable of total containment of a munition's chemical fill, detonation overpressure, and high-velocity fragments
- Reusable

The EDS will be used in situations requiring immediate response to discovery of CWM munitions found to have explosive components and which military explosive ordnance disposal teams have determined to be unsafe for routine handling and transport. The Non-Stockpile Chemical Materiel Project is also evaluating the use of the EDS to treat non-stockpile CWM items (that is, those which are determined to be safe for routine handling and transport) as a cost-effective alternative to deploying other systems.

There will be two models of the EDS: Phase I and Phase II. The EDS Phase I model will be capable of safely withstanding a total explosive detonation of approximately one pound of TNT equivalent. The EDS Phase II will be capable of safely withstanding a total explosive detonation of approximately three pounds of TNT equivalent. Total explosive content means all of the explosives inside the treatment chamber; this includes the shaped charge placed on the munition and the burster and fuze (if present) contained in the munition, as described below.

In order to negate the explosive potential of a munition and treat the munition's chemical fill, the EDS is being designed to intentionally detonate the explosive components of a munition while totally containing both the fragments resulting from detonation and a

munition's chemical fill. The EDS vessel, which is the primary component of the EDS, has been designed to withstand multiple detonations without damage. After detonation, the residual material in the vessel will be treated so that the material could be transported, further treated and disposed of as appropriate. The EDS is being developed as a stand-alone system (although the EDS does not include provisions for electric power generation) to be transportable by ground, water, and air. The different types of non-stockpile CWM munitions that the EDS is being developed to treat include mortar and artillery projectiles that are up to about 8 inches (20 centimeters) in diameter with a net explosive weight of approximately 3 pounds (1.36 kilograms) TNT equivalent, inclusive of the opening and cutting charges.

The following subsections describe the EDS based on current design work. Described are general operation (Section C.5.1), the shaped charge accessing method (Section C.5.2), the treatment process being considered (Section C.5.3), the major components and subsystems (Section C.5.4), the wastes and emissions that will be generated during operations (Section C.5.5), and required resources during operation (Section C.5.6). The EDS will be designed to meet appropriate regulatory requirements.

C.5.1 General Operation

The EDS will only treat one munition at a time. Figure C.5-1 depicts a process flow diagram for the EDS. The munition will be placed into the EDS vessel. Explosive shaped charges will be placed on the munition so that when the charges are fired, they will cause the munition's burster to detonate. In order to ensure that the chemical fill of the munition will be accessed, additional explosive charges will be assembled that will longitudinally cut the munition in the event the munition's burster did not detonate. Fragmentation shields will also be installed in the vessel to ensure that fragments generated do not damage the interior of the vessel when the munition detonates. Chemical neutralization will be used for the treatment of the chemical fills following the rupturing of a munition in the EDS vessel.

The chemical neutralization employed in the EDS is similar to that to be used in the MMD-1 and MMD-2 (see Appendixes C.3 and C.4). In the neutralization process, the appropriate reagents will be pumped into the EDS vessel. The EDS vessel will be agitated, and possibly heated, to mix the contents and thus allow the neutralization reaction to proceed.

When the treatment process is complete, samples will be taken from the vessel to determine treatment effectiveness. The liquid waste in the vessel will be transferred to drums or waste tanks and stored pending shipment for further treatment, as required, and final disposal. Shipment for final treatment and disposal will only occur after the EDS treatment effectiveness has been confirmed. The fragmented munition body, fragmentation shields, and any residual waste will be decontaminated, collected, containerized, characterized, and temporarily stored pending ultimate disposition.

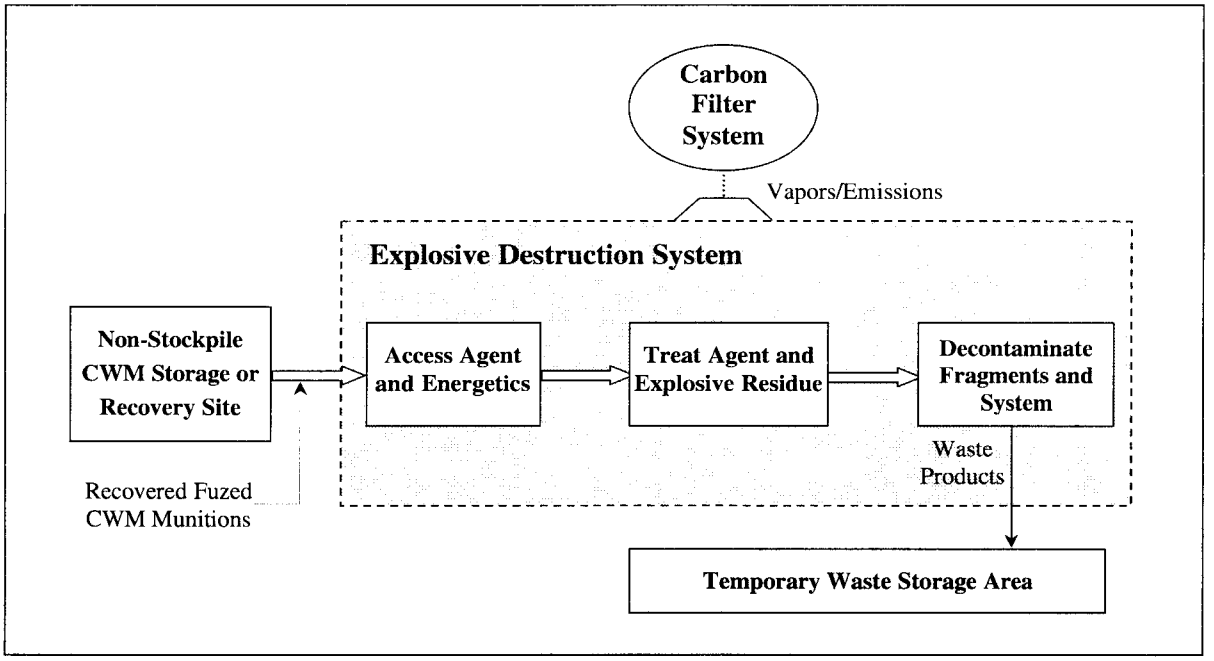


Figure C.5-1. Process Flow Diagram for the Explosive Destruction System

C.5.2 Shaped Charge Munition Accessing

A munition to be processed in the EDS will be attached to a cradle that will then be placed inside the EDS vessel. The cradle will be fitted with several pieces of hardware (for example, holders) that will be mounted onto the cradle and the cradle will be used to position and attach shaped explosive charges to the munition. Fragmentation shields (shock absorbing devices) will also be mounted onto the cradle. The fragmentation shields are expected to be expendable and will not be reused in the accessing of other munitions.

Two types of shaped charges will be used: linear and conical. Linear-shaped charges, depicted in Figure C.5-2, will be used to open the munition casing. Conical-shaped charges, depicted in Figure C.5-3, will be used to detonate the burster in a munition or to access the burster well of a munition if the burster is not present. The linear charges are bendable lengths of explosive filler with a metal sheath (usually lead, copper, or aluminum). The cross section of the charges are v-shaped to direct an explosive "jet" by inverting the "v." The inverted "v" will then cut the munition case along the length of the shaped charge. The charge will be positioned as a loop along the length of a munition to cut out a section of the casing beneath the loop. Conical-shaped charges have a metal core made of copper, aluminum, steel, or glass, and contain an explosive fill material. The conical-shaped charge will invert the core that directs a high velocity jet of linear material into a munition. The size and depth of penetration by both types of charges can be varied by the type of explosive filler, sheathing used, the shape of the charge, and by how the charge is positioned (for example, how far away from the target surface).

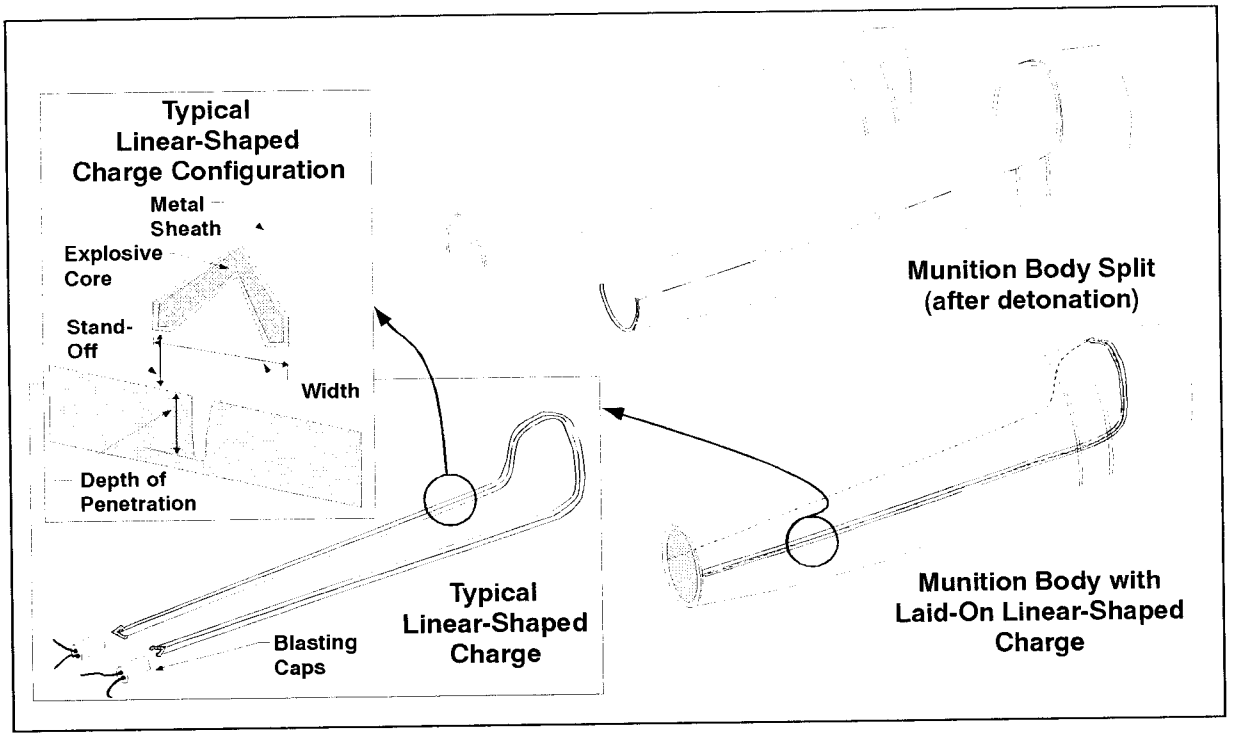


Figure C.5-2. Diagram of a Typical Linear-Shaped Charge Configuration Used in theEmergency Destruction System

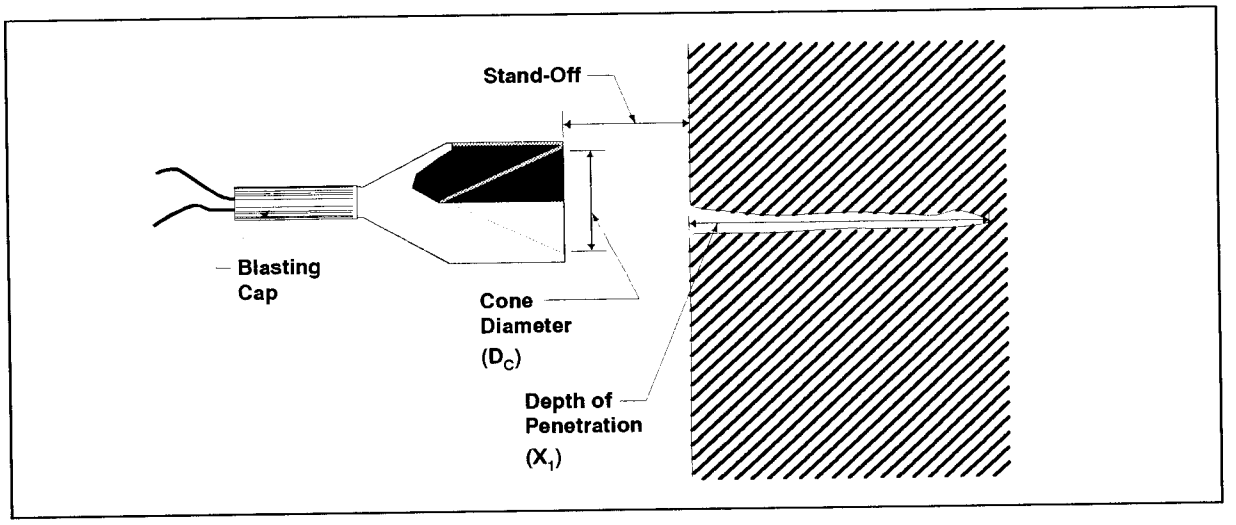


Figure C.5-3. Diagram of a Typical Conical-Shaped Charge Configuration Used in the Emergency Destruction System

The shaped charges will be connected to electrically initiated detonating charges, which have wires that will connect to special ports in the wall of the EDS vessel. The wire leading from the ports on the outside of the vessel will be connected to a firing system. Components of the firing system will include a high voltage capacitor, power supply, a transformer, a trigger and control modules which prevent accidental firing, a spark gap, bite indicators, and continuity meters.

C.5.3 Treatment Processes

Processing non-stockpile CWM munitions in the EDS will include the treatment of the chemical fills and decontamination of the munition casing. Treatment will be considered effective when the liquid waste, metal fragments, and other debris could be handled safely for transportation and ultimate disposal. The treatment reagents that will be used will likely be the same as those used with the MMD-1 and MMD-2.

C.5.4 Major Components of the Explosive Destruction System

The chemical neutralization process will require that the EDS vessel be agitated to ensure adequate mixing of the chemical fills contained in a munition and an appropriate treatment reagent. The EDS vessel must have through-wall perforations for various sampling, monitoring, and operational functions (such as electrical contacts to remotely detonate the shaped charges). The following subsections provide a functional description of the processing components of the EDS.

C.5.4.1 Explosive Destruction System Vessel

The EDS vessel will be situated on a trailer that will be capable of being transported on highways and limited access terrain, and loaded onto boats, barges, railcars, and into aircrafts. The vessel itself will be a stainless steel cylinder with reinforced end plates. The vessel will be able to withstand the explosive forces from the detonation of shaped charges and World War I era 8-inch chemical projectiles with a fuze and burster, as well as containing liquids, vapors, and fragments. The EDS will be equipped with electronic firing devices, vapor sampling lines, and piping to convey liquids and gases.

A cradle assembly with a munition will be moved to the EDS vessel for processing. Just outside of the open door of the vessel, shape charges will be placed on the munition and cradle. The cradle assembly will then be placed into the vessel and the lead wires attached to the high voltage electrical feed through the vessel door. The vessel will then be closed and the munition detonated. The chemical fill will be treated by pumping in the appropriate treatment reagent and mixing by agitating the vessel. The vessel may also be heated. When the reactions are believed to be complete, samples will be taken and analyzed to determine treatment effectiveness. The liquid waste in the vessel will be transferred to containers meeting USDOT specifications. The containers will be appropriately labeled, temporarily stored, and transported

for further treatment (as required) and ultimate disposal after the EDS treatment effectiveness has been confirmed.

After the liquid waste in the EDS vessel has been removed and the vessel decontaminated, the vessel will be opened and the fragmentation shields, metal fragments, munition casing pieces, and other residual wastes removed and containerized.

C.5.4.2 Control System

All detonation and treatment operations are controlled from outside the EDS vessel. Monitoring for chemical agents and industrial chemicals will be conducted using samples and/or confirmation monitors.

C.5.4.3 Utility and Support Systems

The utility and support systems for the EDS are to be designed later in the development process. It is assumed that the EDS will be powered using either electricity available from a local power supply system or a portable generator. Power will be required to operate heaters, cooling systems (if used), hydraulic systems, transfer pumps, lighting, blowers, monitoring, and control equipment.

C.5.5 Wastes and Emissions

Various wastes will be generated from EDS operations. These include (1) liquid, and possibly slurry, wastes from treatment; (2) decontaminated metal munition fragments, pieces of munition casings, and fragmentation shield; (3) spent decontamination solutions and rinse waters; (4) spent filter elements; (5) spent cleanup materials, trash, and debris; and (6) used PPE.

Table C.5-1 lists the wastes that will be generated during EDS operations, the activity or process that will generate each waste, and the physical state of each waste. All wastes generated from EDS operations will be appropriately containerized, except as noted below, and characterized. All wastes directly associated with chemical agent, such as neutralents, will be managed as a hazardous waste. All other wastes that could potentially be contaminated with chemical agent will be sampled and analyzed (as appropriate) for the presence of chemical agent. If present, the waste will be decontaminated (as appropriate) and managed as a hazardous waste. If chemical agent is not present, those wastes will not classify as a hazardous waste under RCRA and may be managed as a non-hazardous waste. Effluents, such as spent decontamination solutions and rinse waters that are determined to be non-hazardous (under RCRA), may be discharged to a sanitary sewer system if one is available. If a local sanitary sewer system is not available, non-hazardous liquid waste will be containerized for disposition at an appropriate wastewater treatment facility.

The amount of liquid waste generated per munition processed in the EDS will be about 330 gallons.

Table C.5-1. Wastes from Operating an Explosive Destruction System at a Treatment Site[a]

Waste Stream	Process of Generation	Physical State	Location for Waste Management[c]
Neutralents	Chemical treatment of chemical agent fills and explosive residues	Liquid[b]	Permitted commercial hazardous waste treatment, storage, and disposal facility (TSDF).
Neutralents	Chemical treatment of industrial chemical fills and explosive residues	Liquid[b]	Permitted commercial hazardous waste TSDF.
Decontaminated metal fragments, pieces of munition casing, and fragmentation shields	Decontamination of chemical agent contaminated metal parts in the EDS vessel after detonation and treatment	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Decontaminated overpacks and packing materials	Unpacking of munitions containing chemicals agent fills from overpacks (spill or leak detected)	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Non-agent contaminated metal fragments, pieces of munition casing, and fragmentation shields	Processing of munition casings and containers with industrial chemical fills (following draining of the fill)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated overpacks	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid (may contain free liquids)	Cleaned and reused. Otherwise, tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Non-agent contaminated packing materials	Unpacking of munitions containing industrial chemicals (spill or leak of industrial chemical identified)	Solid	Tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Uncontaminated overpacks	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Reuse; otherwise, permitted solid waste landfill.
Uncontaminated packing materials	Unpacking of munitions from overpacks (no spill or leak identified)	Solid	Reuse; otherwise, permitted solid waste landfill.

Table C.5-1. (Continued)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[c]
Decontaminated non-metallic munition fragments	Decontamination of agent/non-agent chemical munitions in the EDS vessel after detonation and treatment	Solid (may contain free liquids)	Permitted commercial hazardous waste TSDF.
Spent decontamination solutions and rinse waters	Decontamination, cleaning, and rinsing operations (including emergency personnel decontamination station)	Liquid	Permitted commercial hazardous waste TSDF if used to decontaminate, rinse, or clean anything associated with agent. Otherwise, waste tested to determine if hazardous waste; if hazardous, permitted commercial hazardous waste TSDF; if not, discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent filter elements	Change-out of filter elements from pollution control systems associated with the processing of chemical agent or industrial chemicals	Solid	Permitted commercial hazardous waste TSDF.
Used personal protective equipment[d]	Personal protective equipment generated from treatment system operations	Solid	Permitted commercial hazardous waste TSDF if PPE is used for operation associated with agent. Otherwise, used PPE tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.
Laboratory wastes	Laboratory activities (for example, analysis, calibration, maintenance, and cleaning); spent chemicals and materials	Varies (solid/liquid)	Permitted commercial hazardous waste TSDF if laboratory activity associated with agent. Otherwise, laboratory waste tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if non-hazardous, permitted solid waste landfill or wastewater treatment facility, as applicable.
Spent cleanup materials	Cleanup of spills	Solid	Permitted commercial hazardous waste TSDF if cleanup associated with spill or leak of agent. Otherwise, cleanup materials tested to determine if hazardous waste or solid waste; if hazardous, permitted commercial hazardous waste TSDF; if solid waste, permitted solid waste landfill.

Table C.5-1. (Concluded)

Waste Stream	Process of Generation	Physical State	Location for Waste Management[c]
Trash and similar solid waste	Site personnel daily activities	Solid	Permitted solid waste landfill; municipal solid waste incinerator.
Sanitary waste	Site personnel daily activities	Varies (liquid/solid)	Discharge to existing sanitary sewer system or collection in portable facilities for subsequent treatment at an existing wastewater treatment facility.
Spent oil and lubricants	Equipment maintenance	Liquid	Recycling facility.

[a] Includes wastes from the pre-operational survey

[b] The neutralent waste generated would be dependent upon the chemical agent fills of the chemical munitions to be treated at each site location.

[c] Wastes would be tested for the presence of chemical agent. If present, the waste would be decontaminated and sent to a permitted commercial hazardous waste treatment, storage, and disposal facility regardless of the location indicated in the table.

[d] Single-use PPE would be disposed. Multi-use (reusable) PPE might be cleaned and reused rather than disposed. This would be a site-specific decision based on such factors as practicality, cost-effectiveness, integrity of the item, and availability of laundry facilities.

TSDF—Treatment, storage and disposal facility

The amount of solid waste generated per munition from EDS operations and site activities is likely to be similar to that for MMD-2 operations. However, there will be some reduction in wastes directly related to the number of personnel (such as PPE) because of the smaller crew size for the EDS.

Potential emission points associated with the EDS have not been determined. Depending upon facilities available at a remediation site, small amounts of hazardous contaminants (including reagent vapors) could be released to the atmosphere when the vessel door is opened. However, bulk gas generated during the munition and detonation will be filtered through a carbon filter to ensure that no hazardous releases will be emitted to the atmosphere above permissible levels. Emissions could also occur from the use of an on-site generator for electricity if local power is unavailable. Emissions from an on-site diesel generator, if required, are expected to be small.

C.5.6 Required Resources

Required resources have not been identified for EDS operations. It is expected that the EDS will be operated by a crew similar to that used for response to CWM identification operations and will likely include a senior explosive ordnance disposal technician with technical escort certification, an explosive ordnance disposal safety observer, and two explosive ordnance disposal technicians with technical escort certification. Additionally, two personnel with hazardous waste chemical operations experience will be required.

Water will be needed for the following EDS activities: (1) emergency personnel decontamination station operations, (2) cleaning and decontamination operations, (3) system closure operations, and (4) drinking water supply. Water requirements will be expected to be similar to or less than that for the RRS.

C.6 Holding Facilities

Non-stockpile CWM items that have already been recovered are currently stored pending the availability of the transportable chemical treatment systems described in the previous sections of this chapter or the availability of some other treatment system. This section describes an IHF and other storage facilities that could be used to store non-stockpile CWM awaiting treatment.

C.6.1 Portable Interim Holding Facilities

For non-stockpile sites without appropriate existing structures, the Army has prepared design specifications for and purchased portable buildings designated as IHFs. IHFs are currently available in two sizes: one which is 8 feet (2.4 meters) wide by 16 feet (4.9 meters) long by 8 feet (2.4 meters) high, and the other which is 24 feet (7.3 meters) long by 9 feet (2.7 meters) wide by 8 feet (2.4 meters) high. A secondary containment sump is located below the floor of the portable IHFs which is accessible from outside the IHF. The buildings

have interior and exterior light fixtures. The doors to the IHFs are located in the center on the long side of the building, and the doors are equipped with two hooded high security locking clasps to accommodate padlocks. The larger sized IHFs have two doors. (Department of the Army, 1993; Department of the Army, 1996e)

The IHFs are ventilated by passive airflow through louvered vents located on each end of the building. The controls for the louvered vent are accessible from outside. There are two monitoring ports located near the ceiling and the floor on the side near the entry door. Each port has a threaded cap to allow for monitoring sample lines to be placed inside. The IHFs are equipped with internal self-actuating dry chemical fire suppression units and are constructed with two-hour fire rated walls (Department of the Army, 1993; Department of the Army, 1996e).

The portable IHFs would be installed on a pad and would be anchored in accordance with local building codes. A clear area of at least 50 feet (15 meters) wide would be maintained around the buildings and the area would be cleared of all vegetation and trees that could sustain a fire. If the area is covered by grass, it would be kept mowed. No trees would be allowed in the clear area to help ensure security of the IHF and reduce damage that could be caused by weather. Lightning protection would be installed if the non-stockpile CWM that would be stored is suspected of having explosive components or is flammable. A site for the IHF would be selected or graded to provide adequate drainage. Erosion control measures would be coordinated with locally responsible authorities. Figure 3-29 depicts a typical IHF layout. (Department of the Army, 1993; Department of the Army, 1996e)

The IHF would have the following security equipment to reduce potential vulnerabilities associated with storage of hazardous materials:

- Fencing and/or barriers to prevent inadvertent and unauthorized entry. This would usually be accomplished by use of a 6-foot (1.8-meter) high wire-mesh fence that is permanently installed on posts anchored in concrete.
- Exterior lighting would be provided at the door of the IHF and on a pole near the site to illuminate the exterior of the building.
- Signs would be posted on the fencing to indicate the area is restricted, dangerous, and that unauthorized entry is illegal. Similar signs and conditions of entry would be posted at the gate.
- Communications would be provided by telephone or radio communication. Should an IHF contain munitions with explosive components, radios would not be allowed in the vicinity of the IHF. Signs would be posted on the fence to indicate this restriction.
- When non-stockpile CWM items are being transferred into or out of storage, access control would be implemented.
- The gate and door(s) of the IHF would be locked at all times that entry control access is not in place.

Operation of the IHF would be accomplished in accordance with a site-specific IHF plan. Minimum requirements would include the following:

- All non-stockpile CWM stored in the IHF would be overpacked in NSCMP approved containers.
- All overpacks would be monitored prior to storage.
- Non-stockpile CWM items would not be stacked while in storage.
- IHF(s) would be inspected prior to receipt of any non-stockpile CWM item with records of inspection maintained at the facility.
- Once a non-stockpile CWM item is in storage, the IHF would be locked and entry restricted to properly cleared and trained personnel.
- All non-stockpile CWM received at and shipped from the IHF would be appropriately manifested per RCRA requirements.

In addition to monitoring CWM during packaging and before storage as necessary, three types of monitoring for IHF operations would be conducted: (1) surveillance, (2) first entry, and (3) contingency monitoring. Surveillance monitoring of the IHF would be conducted in accordance with a site-specific plan and would begin once CWM are stored in an IHF. Surveillance monitoring would serve to check the integrity of the overpack containers and identify any chemical agent leakage. Surveillance monitoring would be conducted using low-level (that is, sensitive) monitors to ensure that interior airborne chemical agent concentrations are below workplace exposure levels. Surveillance monitoring would be conducted at least quarterly.

First-entry monitoring would be performed any time the IHF is entered and non-stockpile CWM items containing chemical agents are stored. First-entry monitoring would be conducted remotely using low-level near–real-time monitors to ensure that interior airborne chemical concentrations are below workplace exposure levels. Confirmation monitoring would also be performed with sorbent tubes.

Contingency monitoring would be conducted in response to an emergency contingency action. That would include the detection of a release from the IHF during surveillance monitoring or as a result of an event that could cause a potential release (for example, the IHF being damaged by severe weather).

C.6.2 Other Storage Facilities

In addition to the portable IHF, other storage facilities that could be used for non-stockpile CWM storage would include existing ammunition magazines, which are aboveground structures made of cinder block or other noncombustible materials, and igloos, which are either steel or cast in place arched enclosures that are covered by earth. In storing non-stockpile CWM, existing and fixed storage facilities such as magazines and igloos may

require modifications. The modifications could include sealing drains, modifying ventilators or ventilation systems so that they can be closed, and installing monitoring ports so the interior of the building could be monitored or sampled without personnel entry.

Clear zones and security equipment and procedures at fixed structure storage facilities would be the same as those described for the portable IHFs. Monitoring and maintenance of a fixed facility would also be similar to that described for the portable IHFs and would include those procedures that meet Department of Defense requirements for storage of stockpile chemical materiel.

C.6.3 Army-Approved Containers

When non-stockpile CWM items, including munitions, are recovered they are placed in sealed containers. These containers, which are called overpacks, consist of a metal can-like container large enough to hold a CWM item and cushioning material. Historically, the containers that have been used included the following:

- Empty propellant containers previously used to ship and store propellant for firing artillery projectiles, which are sealed with a metal lid and rubber gasket
- Empty CAIS shipping containers, or pigs, which are metal cylinders closed with a lid that is bolted on using a lead or rubber gasket
- Single round containers designed specifically to contain 155-millimeter and 8-inch artillery projectiles, which have a machined flange and lid with an o-ring seal

Single round containers and similar containers have been designed to meet general USDOT requirements for the transportation of CWM, provide long-term storage capability, and allow for transportation by air. The basis for design of the single round container was an allowable leak rate of less than 1.0×10^{-6} cubic centimeters of helium per second. This is the same standard used for chemical munitions when they were manufactured for the stockpile. The single round containers have been subjected to 40-foot (12-meter) and 6-foot (1.8-meter) drop tests and vibration tests. The single round containers have met the performance oriented packaging criteria in accordance with USDOT and the Military Traffic Management Command requirements. Usually only one item is packaged into an individual container. If the chemical fill of a CWM item was known prior to packing, the overpack container, once loaded with a CWM item, is monitored to ensure it is not leaking.

The Army has procured a family of chemical overpacks known as Army-approved containers (formerly referred to as multiple round containers). Army-approved containers are similar in structure and function to the single round containers, but Army-approved containers were designed to contain a class of munitions based on size, versus a single munition type as with the single round container. The Army-approved container testing program includes the tests required to obtain Army Military Traffic Management Command

and USDOT approval for use. Table 3-18 lists the size and intended use of the Army-approved containers, and Figure 3-30 depicts an example of an Army-approved container.

C.7 Other Support

This section describes other systems that could be used in (1) the analysis of chemical fills of non-stockpile CWM items and wastes generated during the operation of the transportable chemical treatment systems and (2) the identification of the contents of recovered non-stockpile CWM items. In addition, this section also briefly discusses containers that would be used to overpack and transport non-stockpile CWM items.

C.7.1 Laboratory Support

The following subsections describe the Mobile Analytical Support Platform that is designed to accompany the RRS, and a mobile chemical laboratory that is designed to accompany the MMD-1, MMD-2, and possibly the EDS.

C.7.1.1 Mobile Analytical Support Platform

The Army has developed reliable methods for detection of chemical agent in a variety of matrices that are not available in most laboratories. To allow samples to be screened for chemical agent concentration prior to being sent to a RCRA certified laboratory, the Army has acquired a mobile analytical support platform that would be used with the RRS.

The mobile analytical support platform is housed in a trailer that contains a work area and a utility area. The basic vehicle has been adapted to serve as a laboratory platform. The equipment installed in the mobile analytical support platform would operate within Army requirements for certification as a laboratory capable of handling dilute chemical agents. Safety equipment and air filtration systems will conform to Army specifications and Occupational Safety and Health Administration requirements. The latest generation analytical equipment will provide capabilities for chemical agent screening and depot area air monitoring station sample tube analysis. The laboratory would also store and prepare calibration standards for the monitoring equipment that would be used. The laboratory would be operated by a lead chemist and two junior chemists or technicians. Data entry would be provided by the same data entry technician performing data entry for the transportable chemical treatment system.

C.7.1.2 Mobile Chemical Laboratory

A mobile chemical laboratory trailer would be used to conduct laboratory analyses in support of the MMD-1, MMD-2, and possibly the EDS. The laboratory would generally satisfy the Army requirements for a research, development, test, and evaluation facility handling dilute chemical agent solutions. The laboratory would have equipment (for example, gas chromatograph and mass spectrometer) to conduct on-site analyses in support of operations and provide analytical capability during the treatment of non-stockpile CWM. The laboratory would be able to handle agent samples from munitions or containers to verify or determine the chemical fill so that the appropriate treatment reagents and procedures could

be selected. After treatment is complete, the laboratory would perform analyses to determine treatment effectiveness. Initial characterization and categorization of the waste for final disposition would also be done in the laboratory, however, RCRA characterization would be done in RCRA certified laboratories. The mobile chemical laboratory would also perform analysis of depot area air monitoring system station sampling tubes, and store calibration standards for near–real-time monitors. (Department of the Army, 1996f)

C.7.2 Mobile Munitions Assessment System

For munitions or bulk containers that are discovered in the field, a MMAS, Phase I, has been developed to aid in identification of recovered non-stockpile CWM. The Phase I MMAS is designed for use in all seasons and can be subjected to wide variations in temperatures and weather conditions without adversely affecting operations. The MMAS is loaded with an interactive network of nondestructive evaluation, characterization, and assessment equipment, including two radiograph (x-ray) systems, a portable isotopic neutron spectroscopy system, a data acquisition and handling system, gross level air monitors, meteorological stations, agent detection devices, audio and visual equipment, and extensive on-site and off-site communication equipment (INEEL, 1997).

The system has two on board computers for analysis, data processing, collection, and storage as well as a data link to the main MMAS database. The data developed by the MMAS is used to identify munition types; evaluate the condition of chemical munitions; determine if fuzes, bursters or safety and arming devices are in place; and to aid in determining the appropriate methods and safeguards necessary to store, transport, and dispose of agent-filled munitions in a safe and environmentally acceptable manner (INEEL, 1997).

The MMAS equipment is transported in an environmentally controlled goose-neck trailer and is towed by a one ton, four-wheel drive truck. The truck and trailer can be driven on or off roads and can be transported by military cargo planes, if required (INEEL, 1997).

The system is powered by two on board generators and a 12 volt auxiliary battery pack. The main 15 kilowatt generator provides the needed power for the operations conducted in or in the vicinity of the trailer. The 6.5 kilowatt auxiliary generator can be deployed during field operations not in close proximity of the trailer. The 12 volt auxiliary battery pack provides emergency lighting for the trailer. An uninterrupted power supply provides temporary backup power in the event of loss of primary power (INEEL, 1997).

The portable isotopic neutron spectroscopy system is designed to identify chemical compounds inside a recovered munition. The portable isotopic neutron spectroscopy system uses three major pieces of equipment: a shielded Californium neutron source; a high purity germanium gamma-ray detector with a dedicated liquid nitrogen supply; and an electronics package including a Nomad Plus multichannel analyzer, interconnecting cables, and a laptop computer. A detector stand, used to support the detector during field use, is included and is assembled in the field. The stand also holds a moderator, shadow shield, tungsten blocks,

boron carbide plate, and bismuth collimator. The system can be operated by one person (INEEL, 1997).

The MMAS radiography system uses two electric x-ray generators (150 kilovolts and 300 kilovolts) with an imaging subsystem and operator control subsystem. Two x-rays are provided to increase the range of munitions that can be assessed in the MMAS. A light table is also provided for viewing developed x-ray films. A portable radiography unit allows MMAS personnel to produce films of the interior of munitions prior to the munition being moved. The systems also include film processing capabilities while in the field (INEEL, 1997).

A variety of audio and video equipment is provided with the MMAS to document field operations. Still photographs and videotapes of field operations and tasks conducted within the MMAS can be recorded and transmitted to a base station using the external communication equipment (INEEL, 1997).

Local communication consists of computer networking, data transfer from individual subsystems to the MMAS database and two-way radio communications between operating personnel. Long-distance communication includes voice transmission and receiving via cellular phone, and a satellite-based communication and data transmission system. This dual system ensures reliable communication in all areas of the United States (INEEL, 1997).

The air monitoring system consists of the M90 Chemical Warfare Agent Detector manufactured by Environics Oy. The M90 is an automatic electronic instrument used for fast and early detection of military anti-personnel toxic gases that may be present in the air. The M90 is equipped with a small, safe radiation source and does not employ any chemicals or consumables apart from an easy to change mechanical air filter. The M90 can be programmed to detect 31 different non-stockpile chemicals (INEEL, 1997).

The meteorological station included in the MMAS provides wind speed and direction, air temperature, atmospheric stability, air temperature, and barometric pressure. This information supports calculation of a hazard area prior to beginning work with toxic chemicals (INEEL, 1997).

The MMAS has been tested at Dugway Proving Ground in Utah and is currently ready for field use. A Phase II system is being developed that includes all of the Phase I systems plus secondary ion mass spectroscopy, phase (that is, liquid and solid) determination, digital radiography and computed tomography, and low-level air monitoring (INEEL, 1997; Department of the Army, 1997p).

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Appendix D

Summary of Accident Risk Assessment

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Appendix D

Summary of Accident Risk Assessment

D.1 Introduction

An accident risk assessment (Department of the Army, 1999) has been prepared to support the preparation of the *Transportable Treatment Systems for Non-Stockpile Chemical Warfare Materiel Draft Programmatic Environmental Impact Statement* (PEIS). The purpose of the accident risk assessment was to identify the potential risks to the general public if hazardous materials were accidentally released while handling and treating chemical warfare materiel (CWM) or while transporting treatment wastes. The analysis was a programmatic assessment of risk based on generic assumptions about site activities (called unit operations) that would take place with use of the treatment systems described in Section 2 and Appendix C of this environmental impact statement. This appendix provides a summary of the accident risk assessment.

The preferred alternative in the PEIS is to complete the development and testing of treatment systems so that they can be made available to be used to treat and process non-stockpile CWM. The PEIS is also evaluating the no-action alternative, in which the Army would suspend or discontinue the development of these transportable treatment systems and continue to store recovered CWM while assessing and evaluating other CWM processing techniques and methods.

As required by the National Environmental Policy Act, the environmental assessment of a major action must address the impact of this action on public health and safety. Thus, the accident risk assessment is termed "programmatic" only because it is used to support the PEIS. This report addresses the evaluation of public risk from accidental release of hazardous substances during the handling and treatment of non-stockpile CWM. As a point for comparison, the accident risk assessment also evaluates the risk associated with the no-action alternative. In this alternative, the accident risk results from activities associated with the continued storage of recovered CWM (assumed to last up to 10 years).

Risk, as defined in this assessment, is the combination of accident frequency (e.g., accidents per year) and the consequence of the accident (e.g., effect on public health). This accident risk assessment focuses on acute human effects resulting from exposure of the general public to accidental release of (1) chemical agents, (2) weaponized industrial chemicals, and (3) treatment wastes. This document does not address risk to workers. However, worker safety—which is an important consideration in the Non-Stockpile Chemical Materiel Project (NSCMP)—is addressed elsewhere as part of the activities associated with the development of chemical treatment systems.

D.2 Chemical Treatment Systems

The following four types of chemical treatment systems are currently under various stages of development and testing:

- The Rapid Response System (RRS) will be used for treating chemical agent in chemical agent identification set (CAIS) items.
- The Munitions Management Device–Version One (MMD-1) will be used for treating chemical agent and industrial chemicals in munitions without explosive components, in small containers, and in U.S. Department of Transportation (USDOT) bottles.
- The Munitions Management Device–Version Two (MMD-2) will be used for treating chemical munitions with explosive components, and for large bombs and up to one-ton containers with the use of Bulk Item Accessing Equipment.
- The Explosive Destruction System (EDS) will be used to destroy armed fuzed munitions which may detonate during routine handling or transport. A Phase I system capable of withstanding detonation forces of approximately one-pound TNT equivalent has been assembled and will be undergoing tests. A Phase II system, capable of withstanding detonation forces of approximately three-pound TNT equivalent is also under development. The EDS is also being considered for routine destruction of certain types of CWM, and as an alternative to the MMD systems.

These treatment systems are transportable and can be moved from one location to another to treat non-stockpile chemical munitions, containers of chemical agents other than munitions, and CAIS.

D.3 Unit Operations

In order to facilitate understanding of the preferred alternative and the assessment of risks potentially associated with that alternative, the steps that would be involved in handling, treatment, and disposal of non-stockpile CWM, whether directly affected by the alternative or not, are described in terms of discrete "operational units" as shown in Table D-1. For each operational unit affected by the preferred alternative, the potential for risk is assessed. In most instances, treatment of the non-stockpile CWM at the recovery site (or within the facility or installation boundaries where the discovery occurs) would be preferable to treatment at another location (off property). However, conditions at some recovery sites may require movement of the CWM to another location before treatment using a transportable system can be carried out.

For the preferred alternative, the following unit operations were evaluated and assigned to a risk group:

- Interim storage at an interim holding facility (IHF)
- Local ground transport to IHF

Table D-1. Unit Operations Relevant to Preferred and No-Action Alternatives

Unit Operation	Alternative			
	Treatment in Transportable Systems		No Action	
	On-Property Treatment	Off-Property Treatment	On-Property Long-Term Storage	Off-Property Long-Term Storage
Excavation of buried CWM	✓	✓	✓	✓
Identification and packaging of CWM	✓	✓	✓	✓
Local ground transport of CWM to interim storage	✓	✓	✓	✓
On-property or off-property interim storage of CWM	✓	✓		
Local ground transport of CWM to treatment system	✓	✓		
Transport and setup of transportable treatment system	✓	✓		
Treatment of CWM in transportable unit	✓	✓		
Transport of treatment waste to a commercial facility	✓	✓		
Transport of industrial chemicals in CAIS to a commercial facility	✓	✓		
Final disposal of treatment waste and industrial chemicals in a commercial facility	✓	✓		
On-property long-term storage of treatment waste	✓	✓		
Local ground transport of CWM to/from military airfield		✓		✓
Transport of CWM by military air		✓		✓
Off- or on-property long-term storage of CWM			✓	✓

Shaded unit operations are not included in this risk assessment either because (1) they (the first 3 unit operations) are outside of the program mission, (2) they do not involve a release of chemical agent or other hazardous substances, or (3) the actual final treatment method (for final disposal) has not been determined.

- Local ground transport from IHF to airfield (for offsite treatment only)
- Military air transport to another Army installation (for offsite treatment only)
- Treatment
- Transport of treatment wastes and untreated industrial chemicals

For the no-action alternative, the following unit operations were evaluated and assigned to a risk group:

- On-property storage
- Local ground transport from storage to airfield (for off-property storage)
- Military air transport to another Army installation (for off-property storage)
- Off-property storage

The unit operations for which accident risk considerations are discussed but not evaluated (i.e., not assigned to risk groups) include the following:

- Recovery (excavation) of buried CWM
- Identification and packaging of recovered CWM
- Transport and setup of transportable chemical treatment systems
- Final disposal of treatment waste

Excavation accidents can result in release of hazardous chemicals. The associated potential for risks would be of concern at all sites regardless of the treatment strategy selected. However, these risks will be considered by the organization conducting the excavation and making the decision of whether or not to remediate a site.

Identification and packing of recovered CWM, while outside the scope of the accident risk assessment, can affect risk throughout the transport, storage, and treatment processes for CWM. Although this unit operation has not been assigned to a risk group, the frequency of an error in identification has been estimated. This error rate has been used in the accident risk assessment of unit operations involving explosively-configured munitions as a conditional probability estimate that a munition is actually not safe for routine handling (i.e., unstable fuze and explosive train).

Transport and setup of transportable treatment systems do not involve handling or use of military-unique chemicals. Risks from these operations are similar to those for the commercial operations. For example, the setup of a transportable treatment system involves activities similar to routine construction of small buildings or systems. These operations do not pose an accident hazard to the public any more serious than that encountered in routine construction activities. Furthermore, control of these hazards during setup is normally carried out through drafting and approval of a site-specific safety, health, and emergency response plan.

Accident risk of the final disposal of treatment wastes and industrial chemicals at a permitted commercial treatment, storage, and disposal facility (TSDF) is not evaluated since the actual treatment method is a site-specific consideration. However, the Army would still be responsible for ensuring that the wastes and industrial chemicals are treated in a manner that is environmentally safe and protective of public health. The Army plans to closely monitor the TSDF to ensure that Army, federal, and state requirements on health, safety, and environmental protection are met. TSDFs would be equipped with environmental controls to prevent normal release of hazardous chemicals to the environment. Furthermore, it is expected that the accident risk associated with final treatment of wastes could be lower than the risk of treating the CWM using the treatment methods evaluated in this report. This is because the concentration of chemical agent that could be present in the treatment waste would be much lower than that present in a CWM item prior to treatment. The NSCMP will not release any treatment waste to a commercial TSDF if the agent concentration is greater than 50 parts per million (ppm). This 50 ppm limit was established based on the level accuracy of techniques for analyzing chemical agent.

D.4 Site Type Determination

Since actual sites were not being analyzed, it was necessary to develop site types for the assessment that would encompass a range of types and quantities of CWM that would represent most non-stockpile CWM sites. The site types were developed on the basis of data published in the draft *Survey and Analysis Report* (Department of the Army, 1996), and from a review of the buried CWM recovered during past remediation activities, such as the Spring Valley site in Washington, DC, the former Raritan Arsenal in New Jersey, and others (Goldfarb et al., 1996). The review process yielded four general types of CWM to characterize the non-stockpile data: (1) chemical agent identification sets (CAIS), (2) non-explosive munitions (bombs and cylinders), (3) explosive munitions (projectiles, bomblets, land mines, and rockets), and (4) chemical samples. In addition, the Explosive Destruction System (EDS) has a unique mission in the destruction of explosively configured munitions that are not safe for routine handling or transportation, and this type of degraded munition also needed to be characterized. Based on the data reviewed, eight types of non-stockpile CWM sites were developed for this evaluation, as shown in Table D-2. Note that site type H represents a recovered unsafe munition (e.g., considered unsafe for handling and transport). Hence, the only unit operation that applies to site type H is treatment in a transportable unit. While these sites do not necessarily bound the total variety of sites that might be encountered, they can be considered typical of the type of sites for which mobile treatment systems could be employed.

D.4.1 Chemical Agent Identification Sets

During the period 1928–1969, CAIS were widely distributed to military organizations for use in training soldiers to identify chemical agents in the field. A more detailed discussion of CAIS is found in Section 1, and in Appendix B. The original packaging for CAIS comprises two

different types of small glass containers, ampoules and bottles. The most widely used type of CAIS containing chemical agent samples in glass ampoules was the K951 set, each of which contains 48 ampoules (12 phosgene and 36 ampoules of diluted agent). Similarly, the most widely used type of CAIS in glass bottles was the K941 set, which contains 24 bottles of mustard (HD). The draft *Survey and Analysis Report* data yields an average of 277 ampoules or 14 bottles per site. These data formed the basis for the selection of site types A and B (Table D-2).

D.4.2 Non-Explosive Munitions

For non-explosive munitions, the review of existing non-stockpile data determined that the number of intact bombs or cylinders averaged 5 per site, with mustard (HD) and phosgene being equally likely as the chemical fill. The M70 bomb was judged to be the most representative of the group of bombs that contain mustard (H or HD). All phosgene filled bombs were assumed to be M78 bombs, because phosgene was the standard fill for this type. These data formed the basis for site types C and D (Table D-2).

D.4.3 Explosive Munitions

For explosive munitions, the 155-mm projectile was mentioned more frequently than any other projectile in the draft *Survey and Analysis Report*, and had a larger agent fill than the bomblets and most of the mortars. Rockets and land mines were very rare. Mustard was the most frequently mentioned fill type, although sarin (GB) was also suspected in a significant number of cases. This was the basis for selecting site types E and F (Table D-2). Munitions with VX were not considered, as this type of agent was not developed until the 1960s and is highly unlikely to have been disposed of in burial sites.

D.4.4 Chemical Samples

Chemical samples can be found in a variety of containers including glass ampoules, glass bottles, U.S. Department of Transportation (USDOT)-approved cylinders, and ton containers. The ton container is the largest in size of this group, and six sites are known to have at least one ton container. Since sarin (GB) was the most frequently encountered agent in the known ton containers, it became the basis for site type G (Table D-2).

D.4.5 Unsafe Munition

An unsafe explosively configured munition was needed for evaluating the risks associated with the emergency destruction of munitions in the EDS (site type H). Sarin (GB) was selected as the fill type for site type H because it is more volatile than mustard (HD), and therefore evaporates more quickly to form a vapor cloud (Table D-2). Overall, these site types vary according to the type and quantity of CWM, and according to the attendant requirements for the handling, storage, and treatment of the CWM, and for final disposal of the resulting wastes.

D.5 Accident Risk Assessment Methodology

The selected site types vary according to the type of CWM, and according to the attendant requirements for both the handling, storage, and treatment of the CWM and for final disposal of the treatment wastes. Based on these requirements, a set of general assumptions has been defined for each of the site types and for each unit operation. The assumptions are applied across site types, in order to determine the relative risks associated with each treatment strategy. Five essential steps were taken to assess the risks associated with each proposed treatment option. These steps are briefly described below.

D.5.1 Hazard Analysis

The hazards considered in this risk assessment are acute human effects (e.g. death, vomiting, etc.) resulting from exposure to accidental release of chemical agents, weaponized industrial chemicals, and neutralent wastes. Other hazards resulting from unit operation activities (e.g., fire or electrical shock) are considered only with regard to their potential to initiate or enhance release of hazardous substances. The hazard analysis consists of defining site types and identifying accident-initiating events that could lead to release of chemical agent and other hazardous materials. Two types of accident events were considered:

- **Internal initiating events**, which occur as a result of a human error or equipment failure within the unit operation (such as a forklift tine puncturing a CWM overpack).
- **External initiating events**, which occur as a result of forces outside of the unit operation or treatment system (e.g., natural phenomena such as earthquakes, and man-made interferences such as aircraft crashes).

Other external initiating events—such as lightning, hail storms, fires, floods, sinkholes, meteorite strikes, and explosions in nearby operations—were not evaluated in the risk assessment because either (1) the event was considered to be rare or not credible, (2) the impact of the event was considered negligible (for example, hail storms), or (3) conditions for significance of the event were highly site-specific (for example, flooding) or uncertain, and could not be adequately addressed in a programmatic risk assessment. These events would still be evaluated as part of any required site-specific assessment.

D.5.2 Accident Scenario Development

Accident scenario development considers the events following a given accident-initiating event that are necessary for a hazardous materials release to occur or that affect the amount of material released and/or the mode of release (for example, fire-driven release versus evaporative release). These events generally involve the failure of established administrative controls or engineering safeguards. An event tree has been developed for each accident-initiating event identified to model the possible sequence of events following the initiating event, with each path in the event tree representing a unique accident scenario. The logic of events is carried

Table D-2. Site Types Selected for Risk Characterization

Site Type	Type of CWM	Fill[1]	Intact	Contains Explosive	Number of Containers	Items per Container	Total Number of Items	Amount of Agent/Unit	Amount of Agent/ Container	Percent of Agent Remaining in CWM	Treatment Unit
A	CAIS pig[2]	CG	Yes	No	5	12 ampoules	60	0.04 L	0.48 L	100	TSDF
B	CAIS pig	HD	Yes	No	1	24 bottles	24	0.10 L	2.48 L	100	RRS
C	M70 bomb	HD	Yes	No	5	1 bomb	5	60 lb	60 lb	100	MMD-1
C	M70 bomb	HD	No	No	10	1 bomb	10	6 lb	6 lb	10	MMD-1
D	M78 bomb	CG	Yes	No	5	1 bomb	5	205 lb	205 lb	100	MMD-2/BIAE
E	155-mm projectile	HD	Yes	Yes	20	1 projectile	20	11.7 lb	11.7 lb	100	MMD-2/EDS
E	155-mm projectile	HD	No	Yes	50	1 projectile	50	1.17 lb	1.17 lb	10	MMD-2/EDS
F	155-mm projectile	GB	Yes	Yes	20	1 projectile	20	6.5 lb	6.5 lb	100	MMD-2/EDS
F	155-mm projectile	GB	No	Yes	25	1 projectile	25	0.65 lb	0.65 lb	10	MMD-2/EDS
G	Ton container	GB	Yes	No	1	1 TC	1	1600 lb	1600 lb	100	MMD-2/BIAE
H	155-mm projectile (unsafe)	GB	Yes	Yes	1	1 projectile	1	6.5 lb	6.5 lb	100	EDS

[1]Agent or chemical fill; see Glossary.

[2]Normally, there could be up to 4 CAIS items (containing ampoules) in a pig; 1 CAIS/pig is conservatively assumed in this assessment.

EDS – Explosive Destruction System
MMD-1 – Munitions Management Device, Version One
MMD-2 – Munitions Management Device, Version Two
RRS – Rapid Response System
TSDF – Permitted, treatment, storage, and disposal facility for handling industrial hazardous wastes

through to a possibility of either (1) material being released as a result of the event or (2) a material release being prevented by the subsequent events modeled in the event tree.

D.5.3 Accident Frequency Assessment

The frequencies and probabilities of events identified in the accident event trees were based on information from previous studies, including quantitative risk assessments for specific stockpile CWM facilities, the probabilistic risk assessment conducted to support the *Final Programmatic Environmental Impact Statement for the Chemical Stockpile Disposal Program* (Department of the Army, 1988), and published data for commercial truck and military aviation accidents.

After obtaining the accident scenario frequencies, each scenario was assigned to a qualitative frequency category to be used in the risk characterization step. Table D-3 shows the frequency category descriptions. It should be noted that these categories are conservative, in that they encompass a broad range of accident frequencies. The examples shown in Table D-3 are meant only to illustrate how an accident frequency is derived. In the context of the overall risk assessment, an accident in frequency category A can be considered relatively high, while an accident in frequency category C can be considered relatively low.

Table D-3. Accident Frequency Categories

Frequency Category Descriptor	Example of Initiating Event (per Campaign)	Range of Frequency (per Campaign)
May occur (A)	Operator drops a munition[a]	$F \geq 10^{-2}$
Unlikely (B)	Operator drops an overpacked CWM[b]	$10^{-2} > F \geq 10^{-4}$
Extremely unlikely (C)	Container dropped during handling with a forklift[c]	$10^{-4} > F \geq 10^{-6}$
Rare (D)	Large aircraft crashes on a storage facility[d]	$F < 10^{-6}$

[a] Assuming that the frequency of dropping a munition is 6×10^{-4} per operation and there are a total of 20 operations throughout the campaign that could lead to dropping the munition, the total campaign frequency is 1.2×10^{-2}.

[b] Assuming that the frequency of dropping a munition is 6×10^{-4} per operation. If there are a total of 15 operations throughout the campaign that could lead to dropping the container, the total campaign frequency is 9.0×10^{-3}.

[c] Assuming that the frequency dropping an item using a forklift is 1×10^{-5} per operation. If there are 2 operations throughout the campaign that could lead to dropping the container, the total campaign frequency is 2.0×10^{-5}.

[d] Assuming a large aircraft crash frequency is 7.5×10^{-8} per campaign.

D.5.4 Accident Consequence Assessment

Analyzing the consequences resulting from an accident scenario involves (1) estimating agent release quantities and release modes (e.g., via evaporation) and (2) estimating downwind effects that could result from the release(s) using the D2PC model, an atmospheric dispersion model developed by the Army under the stockpile CWM program specifically to model chemical warfare agent releases (Whitacre and Myirski, 1987; Innovative Emergency Management, 1993). The exposure limits for agents used by D2PC for this analysis correspond to two levels of health impact: (1) no-effects and (2) no-deaths. The no-effects threshold is the maximum dosage that a healthy individual could receive and show no significant effects of chemical agent exposure. The no-deaths threshold is the maximum dosage that can be received by an individual without death occurring. The D2PC output is cast in terms of the maximum distances downwind of a specified release at which these exposure thresholds would be exceeded for the specified meteorological conditions. Table D-4 identifies the chemical dose numbers used in the D2PC model to correspond to the no-death and no-effects thresholds for acute exposure. The D2PC model no-effect and no-deaths levels are currently under review and may be revised in the future. Site-specific risk assessments that might be conducted in the future would incorporate any revised D2PC model no-effect levels that may be reported as a result of the review.

Each site type and accident scenario pairing is unique as to the number of munitions involved and the quantity of chemical agent potentially released. Thus, if only one munition is affected by an accident event (a forklift drop of an overpacked munition) only the contents of that munition could be released. For accident scenarios involving more than one CWM item, the number of items assumed to release chemical agent is determined on a case-by-case basis. For example, in the scenario of an aircraft crash onto the Munitions Management Device–Version Two (MMD-2) treatment facility for site type E, it is assumed that ten munitions out of the total site inventory would be breached. This is based on two munitions being processed, as well as a full load of eight munitions present in the munition warming cabinet at the time of the accident.

Table D-4. Threshold Dosages Utilized in the D2PC Model

Chemical	No Deaths Threshold (mg-min/m^3)	No Effects Threshold (mg-min/m^3)
Mustard, Lewisite	100	2
VX	1.76	0.44
GB	6	0.5
Phosgene	320	10
Cyanogen Chloride	1850	1525

Severity categories are defined in terms of the minimum distances at which there are no-deaths or no-effects with respect to the work zone and the controlled area. The work zone is defined as the area around an operation in which entry is strictly limited, e.g., an environmental enclosure or a fence. For this accident risk assessment, the work zone is assumed to have an area with a 25 m radius, centered on the work area of concern (that is, where work or treatment is actually occurring). The controlled area is defined as the area around an operation in which all non-workers are evacuated, or the area for which an evacuation plan would be prepared. Since the controlled area varies from site to site, severity categories for this accident risk assessment are assigned to accident scenarios for three specified controlled areas (areas with radii of 200 m; 1,000 m; and 2,000 m) and centered on the operation of concern. Selection of these distances was intended to allow for a reasonable delineation between the no-deaths and no-effects hazard distances. For example, selecting a narrower range of distances (e.g., 200, 400, and 600 m) would not be sufficient to delineate the accident scenarios into the four groups of severity categories. The same would be true if the range of control distances established were too wide, e.g., between 200 and 20,000 m. The severity categories for accidents involving chemical agent are given in Table D-5.

Accident severity categories associated with release of industrial chemicals and treatment wastes during transportation are treated somewhat differently than those for chemical agent releases. Due to the programmatic nature of this assessment, a qualitative measure of the severity is adopted based on normal USDOT emergency response procedures. In a typical transportation accident involving a hazardous substance release, the Emergency Response Unit would establish the following control zones: (a) exclusion zone is the area where a chemical or contaminant spill has occurred (or could occur); (b) contamination reduction zone is the area between the contaminated area and the clean or non-hazardous area; and (c) support zone is the area used for administrative and support functions that are required to maintain efficient cleanup operations in the exclusion zone. Table D-5 defines the severity categories established on the basis of these control zones.

Table D-5. Accident Severity Categories for Chemical Agent Release

Category Number	Definition
I	$CA < PD_{ND}$
II	$PD_{ND} < CA < PD_{NE}$
III	$WZ < PD_{NE} < CA$
IV	$PD_{NE} < WZ$

CA – controlled area

PD_{ND} – plume distance to no deaths;

PD_{NE} – plume distance to no effects

WZ –work zone.

Table D-6. Accident Severity Categories For Transportation Accidents Involving Release of Treatment Wastes and Industrial Chemicals

Category Number	Definition
1	$CRZ < PD_{ND}$
2	$PD_{ND} < CRZ < PD_{NE}$
3	$EZ < PD_{NE} < CRZ$
4	$PD_{NE} < EZ$

CRZ – contamination reduction zone limiting boundary

EZ – exclusion zone limiting boundary.

PD_{ND} – plume distance to no deaths

PD_{NE} – plume distance to no effects

D.5.5 Risk Characterization

For each unit operation, the combination of the accident scenario frequency category and severity category assignments were used to develop a comparative estimate of risk (upper risk group, intermediate risk group, or lower risk group). The risk matrix developed for the accidents involving chemical agent release[1] is shown in Table D-7, while the matrix specifically developed for highway transportation accidents involving the transport of treatment wastes and industrial chemicals is shown in Table D-8. These risk estimates were reviewed, and major contributors to risk for the unit operation were identified. The highest risk group assigned to any accident scenario for a given unit operation and site type was selected to represent that unit operation as a whole for the given site type. For example, site type C has one forklift operation accident scenario that fell into the intermediate risk group, and several accident scenarios that were in the lower risk group, so the overall risk classification for local transportation and handling for site type C was intermediate. These assigned risk groups were then used to compare unit operation risks, and to make observations about risk differences among the treatment options.

To put this risk characterization approach into perspective, it can be said that accidents in the upper risk group must have accident frequencies greater than or equal to 1 in 10,000 and that there is a possibility, albeit small, that chemical agent release from such accidents would cause one or more fatalities because the estimated "no deaths" distance exceeds the established controlled area (see Table D-7). Accidents in the upper risk group require mitigation to ensure public health and safety.

[1] For the purpose of the air dispersion analysis, the industrial chemical—phosgene (CG)—is considered a chemical agent.

Table D-7. Risk Matrix for Accidents Involving Chemical Agent Release

Frequency Category	Severity Category			
	I CA < PD_{ND}	II PD_{ND} < CA < PD_{NE}	III WZ < PD_{NE} < CA	IV PD_{NE} < WZ
May occur (A)	●	●	□	
Unlikely (B)	●	□	□	
Extremely unlikely (C)	□			
Rare (D)				

● – upper risk group □ – intermediate risk group – lower risk group
CA – Controlled area
PD_{ND} – Plume distance to no deaths
PD_{NE} – Plume distance to no effects
WZ – Work zone.

Table D-8. Risk Matrix for Highway Transportation Accidents Involving Treatment Wastes and Industrial Chemicals

Frequency Category	Severity Category			
	1 CRZ < PD_{ND}	2 PD_{ND} < CRZ < PD_{NE}	3 EZ < PD_{NE} < CRZ	4 PD_{NE} < EZ
May occur (A)	●	●	□	
Unlikely (B)	●	□	□	
Extremely unlikely (C)	□			
Rare (D)				

● – upper risk group □ – intermediate risk group – lower risk group
CRZ – contamination reduction zone limiting boundary
EZ – exclusion zone limiting boundary
PD_{ND} – plume distance to no deaths
PD_{NE} – plume distance to no effects

D.6 Risk Contributors

The results of the accident risk assessment have been examined to identify the accident scenarios that are dominant risk contributors for each unit operation. The risk ranking of the unit operation for each site type is based on the accident scenario(s) that falls in the highest risk group. The risk results for those operations affected by the preferred alternative (i.e., use transportable treatment systems to treat recovered CWM) are summarized in Table D-9 and discussed below.

D.6.1 Interim Storage

IHFs are used to provide temporary, safe, and secure storage of CWM recovered during the remediation operations at a non-stockpile burial site. A portable facility is selected to represent the IHF. General observations on the relative risk for this unit operation, by site type, are as follows:

- A small aircraft crash is identified as the dominant contributor for the interim storage unit operation. Chemical agents may be released into the environment as a result of the overpacked CWM being damaged or detonated by the impact. If an explosively configured CWM item turns out to be unsafe, detonation is highly likely.
- This unit operation falls in the lower risk group for site type B for all the controlled areas considered. The risk falls in the intermediate risk group for site type A for a controlled area at 200-m radius; site types C and E for controlled areas at 1,000-m radius or less; and site types D, F, and G for all controlled areas.

D.6.2 Local Ground Transport of Chemical Warfare Materiel

This unit operation encompasses (1) ground transportation and handling required to move non-stockpile CWM from interim storage to an onsite treatment system; and (2) ground transportation and handling required to move non-stockpile CWM from interim storage to a military airfield (helicopter takeoff site) for offsite transport, followed by ground transportation from a destination military airfield (helicopter landing site) to an offsite storage facility. The activities associated with offsite treatment and storage include handling operations associated with transfer of CWM from a helicopter to a fixed-wing aircraft, and from the fixed-wing aircraft to a second helicopter. The two ground transportation operations are evaluated separately to facilitate use of the results in discussing treatment options.

General observations on accident scenarios affecting the local ground transportation unit operation are as follows:

- For handling operations, the dominant risk contributor is accidental forklift tine impact with overpacked CWM or a ton container, leading to an agent spill. Forklift accidents can result in agent release from only one CWM item.

Table D-9. Summary of Risk Group Assignments for Unit Operations for the Preferred Alternative

Controlled Area for Treatment System (meters)	Unit Operation				
	At Treatment Site			Transport to Treatment Location	
	Interim Storage in Portable Buildings	Transport and Handling[a]	Treatment	Transport and Handling[b]	Air Transport
Site type A, CAIS Only (CAIS with Phosgene [CG])					
			RRS		
200	□	○	○	□	○
1,000	○	○	○	□	
2,000	○	○	○	□	
Site type B, CAIS Only (CAIS with Mustard [HD])					
			RRS		
200	○	○	○	○	○
1,000	○	○	○	○	
2,000	○	○	○	○	
Site type C, Non-Explosive Munitions (M70 bombs with Mustard[HD])					
			MMD-1		
200	□	□	□	□	□
1,000	□	□	○	□	
2,000	○	□	○	□	
Site type E, Explosive Munitions (155-mm projectiles with Mustard [HD])					
			MMD-2 / EDS		
200	□	□	□ / □	□	
1,000	□	□	○ / □	□	
2,000	○	□	○ / □	□	
Site type F, Explosive Munitions (155-mm projectiles with Sarin [GB])					
			MMD-2 / EDS		
200	□	□	□ /	□	
1,000	□	□	□ /	□	
2,000	□	□	□ / □	□	
Site type G, Chemical Samples (Ton container with Sarin [GB])					
			MMD-2		
200	□	□	□	□	□
1,000	□	□	□	□	
2,000	□	□	□	□	
Site type H, Unsafe Munition (155-mm projectile with Sarin [GB])[c]					
			EDS		
200	NA	NA		NA	NA
1,000	NA	NA		NA	
2,000	NA	NA	□	NA	

– upper risk group □ – intermediate risk group ○ – lower risk group.

[a] Transportation and handling between interim storage facility and treatment system.

[b] Transportation and handling between interim storage facility and military airfield by truck, and between destination military airfield and storage facility.

[c] Analyzed only for the treatment unit operation using the EDS. Munition unsafe to move to an MMD-2.

CAIS – chemical agent identification set
EDS – Explosive Destruction System
mm – millimeter
MMD-1 – Munitions Management Device–Version One
MMD-2 – Munitions Management Device–Version Two
NA – not applicable
RRS – Rapid Response System

For site type A, the first ground transportation segment involving movement of the CWM from the IHF to the onsite treatment facility is in the lower risk group category. The second ground transportation segment for CWM movement to and from a military airfield involves more forklift movement operations—placing the ground transportation accident risk in the intermediate risk group category.

- Site type B falls in the lower risk group category for both onsite and offsite ground transportation segments. Other site types fall in the intermediate risk group for both segments. For site types C, E, F, and G, the forklift tine accident scenario is assigned to frequency category B, and the severity category is either II or III depending on the size of the controlled area.
- The risk group assignment for site type D is influenced by the size of the controlled area considered in this evaluation. Site type D falls in the intermediate risk group for the 200-m controlled area radius. In this situation, the severity of the release influences the relative risk ranking rather than the scenario frequency, which is category C for site type D.

D.6.3 Treatment Using Transportable Systems

This unit operation involves treatment of various types of CWM using transportable chemical treatment systems that are appropriate for the munitions at each site type:

- RRS treats CAIS items (represented by site types A and B)
- MMD-1 treats munitions and containers that do not have explosive components (represented by site type C)
- MMD-2 treats munitions and containers with explosive components (represented by site types E and F)
- MMD-2 with the Bulk Item Accessing Equipment is used to access large munitions and bulk containers without explosive components (represented by site types D and G) with neutralization conducted in the MMD-2
- EDS is used to treat munitions that are found to be unsafe to routinely handle and transport. The EDS is also being considered for treatment of certain munitions that can be handled safely, i.e., in lieu of the MMD-2 (or possibly MMD-1)

D.6.3.1 Treatment in the Rapid Response System (RRS)

General observations on the accident risk associated with the Rapid Response System (RRS) treatment operation are as follows:

- Use of the RRS to separate site type A phosgene (CG) ampoules from other CAIS ampoules and to treat site type B CAIS items falls in the lower risk group. There are no accident scenarios involving release of agent outside of engineering controls for these site types unless there is complete failure of engineering controls.

- Earthquakes are judged to be the most likely cause of engineering control failure. The very low probability of these events, coupled with the relatively small "no effects" distances, result in assignment to the lower risk group.

D.6.3.2 Treatment in the Munitions Management Device–Version One (MMD-1)

For this assessment, the MMD-1 is applied to site type C only. General observations on the accident risk associated with the MMD-1 treatment operation are as follows:

- The dominant accident risk contributor is an earthquake that leads to loss of engineering controls.
- Accident risk at site type C (with distilled mustard [HD]) falls in the intermediate risk group if the controlled area is limited to a 200-m radius; it falls in the lower risk group if the controlled area is at 1,000-m or 2,000-m radius.

D.6.3.3 Treatment in the Munitions Management Device–Version Two (MMD-2)

For this assessment the MMD-2 is used to treat explosively-configured 155-mm projectiles at site types E and F. General observations on the accident risk associated with the MMD-2 treatment operation are as follows:

- For site types E and F, an earthquake or tornado is the dominant risk contributor. The event leads to the accidental detonation of an unsafe projectile in the MMD-2. High-speed fragments from an exploding projectile could cause physical damage to the system.
- Site type E (with HD) falls in the intermediate risk group only when the controlled area is limited to 200 m.
- Site type F (with sarin [GB]) falls in the intermediate risk group, regardless of the size of the controlled area. The intermediate risk ranking for site type F is influenced by the relatively more severe consequences arising from the release of GB as compared to HD (for site type E).

D.6.3.4 Treatment in the Munitions Management Device–Version Two (MMD-2) Using the Bulk Item Accessing Equipment

General observations on the accident risk associated with this treatment operation are as follows:

- An earthquake that leads to loss of engineering controls is the dominant risk contributor.
- The accident risk for site types D (with CG) and G (with GB) falls in the intermediate risk group, for the three sizes of controlled area considered in this assessment. This risk ranking is predominantly influenced by the severity of the release (category I).

D.6.3.5 Treatment in the Explosive Destruction System (EDS)

Using the EDS to treat unsafe (explosively-configured) munitions upon recovery is not representative of the site types selected for evaluating accident risk associated with the other

transportable treatment systems. For this reason, site type H is designated to represent a hypothetical site where the EDS will be used under non-routine situations. General observations on accident scenarios affecting the EDS treatment operation are as follows:

- Treatment of a 155-mm projectile with GB that is unsafe to move falls in the upper risk group (except for controlled area = 2,000 meters).
- The major risk contributor is the scenario where the operator drops a munition, which then results in detonation or agent spill.

The EDS may also be used to treat, under routine situations, explosively configured munitions similar to those selected to represent site types E and F.

- For site type E, this unit operation falls in the intermediate risk group for each controlled area considered.
- Using the EDS to treat 155-mm projectiles with GB at site type F falls in the upper risk group (except for controlled area = 2,000 meters).
- The major risk contributor is the scenario where the operator drops an intact munition that results in agent spill. Although the same accident scenarios applies to both site types E and F, the risk group characterization for site type E is relatively lower ant that for site type F, largely because mustard (HD) is not as volatile as GB.

D.6.4 Transport of Chemical Warfare Materiel by Military Aircraft

This unit operation includes movement of CWM by (1) helicopter to a fixed-wing aircraft runway, (2) fixed-wing aircraft to a military airfield near the destination site, and (3) helicopter from this airfield to a landing site on or near the destination storage or treatment site. To ensure completeness, both helicopter and fixed-wing aircraft movements are evaluated. However, some sites may not require use of both types of aircraft for offsite transportation. General observations on accident risk for this unit operation are as follows:

- Certain accident scenarios involving transport of CWM by helicopter for site types C, E, and F fall in the intermediate risk group. However, similar scenarios involving transport by fixed-wing aircraft accidents fall in the lower risk group. This disparity in risk groups is due to the higher historical accident rates for the assumed helicopter (UH-1).
- The air transportation operations are assigned to the lower risk group for site types A and B, and to the intermediate risk group for site types C, D, and G. Site types E and F fall in the upper risk group because they involve the movement of larger numbers of CWM items.

D.6.5 Transport of Industrial Chemicals and Treatment Wastes

This unit operation includes the transport of CAIS items containing industrial chemicals (e.g., CG) and treatment wastes (from RRS, MMD-1, MMD-2, and EDS processes) to a permitted commercial TSDF. This unit operation applies to both onsite and offsite treatment

options. General observations on the accident risk associated with this unit operation are as follows:

- For the handling and transport of neutralent waste drums from site types B through G, accidents that involve a breach of the drums (either by forklift during handling or in association with a truck collision or rollover) are in the intermediate risk group. Risk associated with the transport of RRS neutralent waste (site type B) is influenced primarily by the amount of chloroform present in the neutralent waste, which presents a health hazard if it is accidentally released and dispersed by air. Risk associated with the transport of MMD-1 or MMD-2 neutralent wastes (site types C through G) is influenced more by the accident frequency because the waste drums do not afford any significant protection from puncture in the event of a truck collision, and more truck trips will be required to transport the total amount of neutralent wastes generated from these treatment processes.
- Overall, the activity of handling and transporting industrial chemical CAIS (site type A) falls in the lower risk group. This finding is attributed to the lower frequency category for breaching CAIS items that are being transported in multiple-round containers as compared to breaching the 55-gallon waste drums (for site types B through G above).

D.6.6 Long-Term Storage of Treatment Wastes

Site type A is not evaluated for this unit operation because CAIS items containing industrial chemicals such as CG, will not be neutralized in the RRS. These items will be transported by truck to a commercial TSDF for treatment and disposal. General observations on the accident risk associated with this unit operation are as follows:

- For site type B, this unit operation falls in the intermediate risk group. Forklift tine puncture leading to the release of RRS neutralent (which contains 50 to 87 percent chloroform) is the dominant risk contributor. The waste drums do not afford any significant protection from forklift tine puncture in the event of a forklift collision.
- The accident risk for this unit operation for all the other site types (C through G) falls in the lower risk group. These results are primarily influenced by the fact that the MMD-1, MMD-2, and EDS neutralents do not pose an inhalation hazard.

D.7 Comparison of Risks for On- and Off-Property Treatment

Relative to on-property treatment, the off-property treatment option imposes additional accident risks. As shown in Table D-9, this option necessitates two additional unit operations: (1) local ground transportation of CWM to and from a military airfield and (2) military air transport to the storage/treatment location. For off-property treatment, accident risks posed by these additional unit operations are treated as add-on risks. While the

NSCMP plans to pursue on-property treatment, off-property treatment cannot be ruled out at this time. This will be a site-specific decision, thus ways to mitigate the add-on risk imposed by movement of the CWM to another location will require site-specific analysis.

D.8 Long-Term Storage (No-Action Alternative)

As stated earlier, the no-action alternative would forego or suspend the current development of the four treatment systems and continue to store recovered non-stockpile CWM until alternative treatment methods are developed and tested. The accident risk assessment assumed a 10-year continued storage period.

The long-term storage facilities may be located on-property or off-property depending on site conditions. Both the portable storage facility and igloo have been selected as the storage facilities for the long-term storage alternative. A portable storage facility is assumed for on-property storage. An igloo is assumed for off-property storage. A summary of the accident risk assessment results is presented in Table D-10. Additional unit operations would be involved if the recovered CWM were to be transported to another location for storage; risks for those operations will also apply to off-property long-term storage and should be considered as add-on risks. Furthermore, the risks associated with an accidental release from a future treatment system cannot be determined at this time because it is not known what that system could be. Assuming that the future treatment system would have the same risks as the proposed treatment systems, the overall risk of the no-action alternative could be viewed as the sum of the risks represented in the unit operations shown in Tables D-9 and D-10.

D.8.1 Long-Term Storage in a Portable Facility

The portable long-term storage facility for on-property long-term storage is the same as the portable interim storage facility with longer storage duration (10 years). General observations on the accident risk associated with this unit operation are as follows:

- Small aircraft crashes are identified as the dominant risk contributors for the long-term storage unit operation for all site types. This event falls in frequency category C (Extremely Unlikely).
- Small aircraft crash scenarios, which involve the release of more volatile chemical agents (i.e., GB and CG), are assigned to severity category I for the three sizes of controlled areas considered. For site types D, F, and G, this unit operation is assigned to the intermediate risk group. For site types, A, C and E, the risk is assigned to the intermediate group for the smaller control area sizes, but drops down to the lower risk groups for the larger control areas.
- Earthquakes and tornadoes are also dominant risk contributors for sites storing munitions with explosive components. Chemical agents may be released if the overpacked CWM is damaged or detonated by impact forces.

Table D-10. Summary of Accident Risk Assessment Results for Long-Term Storage (No-Action Alternative)

No-Action Alternative: Long-Term Storage				
	On-Property Storage	Off-Property Storage		
Controlled Area (meters)	Storage in a Portable Facility	Transport and Handling[a]	Air Transport[b]	Storage in an Igloo
Site type A (CAIS with Ampoules of Phosgene [CG])				
200	□	□	○	○
1,000	○	□		○
2,000	○	□		○
Site type B (CAIS with Bottles of Mustard [HD])				
200	○	○	○	○
1,000	○	○		○
2,000	○	○		○
Site type C (M70 Bomb with Mustard [HD])				
200	□	□	□	○
1,000	□	□		○
2,000	○	□		○
Site type D (M78 Bomb with Phosgene [CG])				
200	□	□	□	○
1,000	□	○		○
2,000	□	○		○
Site type E (155-mm Projectile with Mustard [HD])				
200	□	□		○
1,000	□	□		○
2,000	○	□		○
Site type F (155-mm Projectile with Sarin [GB])				
200	□	□		○
1,000	□	□		○
2,000	□	□		○
Site type G (Ton Container with Sarin [GB])				
200	□	□	□	○
1,000	□	□		○
2,000	□	□		○

– upper risk group □– intermediate risk group ○– lower risk group.

[a]Transportation and handling between interim storage facility and military airfield and between destination military airfield and off-site storage facility.

[b]Controlled area designation does not apply to air transport.

CAIS – Chemical agent identification set

D.8.2 Long-Term Storage in an Earth-Covered Igloo

As noted, earth-covered igloos are designed to withstand credible external events such as earthquakes, tornadoes, and aircraft crashes. Because of the high structural strength of the igloo, the crash of a small aircraft is not expected to breach an igloo or affect its structural integrity. The potential for a tornado-generated missile to penetrate an igloo is considered to be "Rare" based on its robust design. Igloos have been shown to withstand very large earthquakes without gross failure (they are designed to withstand peak ground acceleration [pga] of 1.9g [where g stands for acceleration due to gravity]). Therefore, damage of stored CWM inside an igloo as a result of earthquakes, small aircraft crashes, or tornado-generated missiles is not expected. Consequently, these scenarios are assigned to the lower risk group for all site types and controlled areas.

For the no-action alternative, on-property long-term storage using portable storage facilities falls in the intermediate risk group, especially for the 200-m controlled area. With larger controlled areas, some accident scenarios are assigned to the lower risk group. All accident scenarios are assigned to the lower risk group if a storage igloo is used. Of course, as the storage period is extended, there would be a greater chance that the accident risk could go up because of the deteriorated state of the recovered CWM. This possibility is not reflected in the risk results.

D.9 Potential Mitigation

Risk reduction measures that could be implemented for each unit operation were analyzed to determine the effect on risk group assignments for the appropriate site types. These measures, and the resulting changes in risk, are shown in Table D-11.

D.10 Sensitivity Analyses

Sensitivity analyses were carried out to determine the sensitivity of the risk results to different scenario assumptions. A sensitivity analysis of the results of the D2PC model to changes in the model input parameters was performed, as well as the sensitivity of the risk results to the number of CWM items that would be loaded onto a truck, and use of larger-capacity aircraft.

D.10.1 Sensitivity of Results to Air Dispersion Modeling Parameters

The D2PC model is used by the U.S. Army to support the Chemical Stockpile Emergency Preparedness Program, and the site-specific NSCMP hazard analyses. It was developed specifically to model chemical warfare agent releases, and incorporates detailed information on the type of accident (for example, explosion, fire, or spill) and the duration of agent release. The effects of changing the values for model input parameter assumptions on the hazard distance calculations were examined, as well as the resulting effects on severity category rankings. The input parameters examined include atmospheric stability, wind speed,

Table D-11. Potential Risk Mitigation Measures

Unit Operation	Site Type	Risk Group without Mitigation	Potential Mitigation	Risk Group with Mitigation
Interim Storage	D, F, G	□	Use storage igloos or restrict air traffic.	❍
	A, C, E	□	Increase size of the controlled area.	❍
Local Ground Transportation (from IHF to Treatment Unit)	C, D, E, F, & G	□	Utilize forklifts designed to minimize breaching of CWM/overpack.	❍
Local Ground Transportation (from IHF to/from military airfield)	A, C, E, F, & G	□	Utilize forklifts designed to minimize breaching of CWM/overpack.	❍
	D	□	Increase size of the controlled area.	❍
RRS Treatment	A & B	❍	None required	❍
MMD-1 Treatment	C	□	Increase size of the controlled area.	❍
MMD-2 Treatment	E	□	Increase size of the controlled area.	❍
	F	□	Utilize better methods for identifying unsafe munitions or estimating existing method accuracy; increase size of the controlled area; and limit operation to one munition at a time.	❍
Bulk Item Accessing Equipment/MMD-2 Treatment	D & G	□	Perform more detailed analysis of engineering controls that could fail as a result of an earthquake.	❍
EDS Treatment[2]	E	□	Use environmental enclosure and/or increase size of the controlled area.	❍
	F		Use environmental enclosure and/or increase size of the controlled area.	□
	H		Increase size of the controlled area.	□
Military Air Transport	F	□	Use fixed-wing aircraft instead of UH1 helicopter.	❍

– upper risk group □ – intermediate risk group ❍ – lower risk group.

[2] More detailed design information could lead to an improved estimate of the EDS vessel failure probability value used in this assessment.

Table D-11. (Concluded)

Unit Operation	Site Type	Risk Group without Mitigation	Potential Mitigation	Risk Group with Mitigation
Transport of Treatment Wastes and Industrial Chemicals	B	□	Avoid highly populated areas; limit ground transportation to daytime operations; use puncture-resistant overpacks.	❍
	C, D, E, & F	□	Avoid highly populated areas.	❍
Long-Term Storage of Treatment Wastes	B	□	Utilize forklifts designed to minimize puncture accidents.	❍
Long-Term Storage (On-property)	A, C, D, E, F & G	□	Use storage igloos.	❍
Long-Term Storage (Off-property)	All	❍	None required.	❍

– upper risk group □ – intermediate risk group ❍ – lower risk group.

ambient temperature, height of mixing layer, atmospheric pressure, time for emergency response, release fraction, and dose limits.

The sensitivity analysis showed that, for most of the input assumptions, variations in parameter selection could change the model outcome, as measured by the "no deaths" hazard distance, by up to 50 percent. While not insignificant, changes of this magnitude are not expected to alter the conclusions of the analysis regarding the relative merits of proceeding with the development of NSCM treatment systems. The two modeling parameters that had a more substantial impact were (1) the potential for E stability (slightly stable) atmospheric conditions, compared to neutral conditions, during daytime operations, and (2) the possibility of changes in Army-approved dosages corresponding to health impacts. These two parameters could increase the severity category from II to I, if the initially established controlled area has a radius of 2,000 m.

Stability E meteorological conditions could occur during dawn or dusk timeframes as meteorological conditions transition between the daytime neutral situation and nighttime stable conditions. As a mitigating option, meteorological conditions could be monitored, and operational activities halted or terminated at the onset of stable conditions.

D.10.2 Other Sensitivity Analyses

In addition to D2PC model parameters, a sensitivity analysis was performed to compare transporting one munition versus five munitions per truck movement during ground transportation activities. The sensitivity study contrasted the reduced campaign frequency of accident occurrence if five munitions were transported simultaneously (fewer truck trips

needed) with the increased amount of agent available for release if a truck accident were to occur. For all scenarios, the truck accident frequencies for both the one-munition and five-munition cases were in the frequency category D ("Rare"), and therefore no corresponding difference was seen in the subsequent risk comparison.

The sensitivity of using a larger fixed-wing aircraft (C-130) rather than the base case, C-12 cargo plane, was also considered. The C-130 has a larger cargo capacity, and the analysis compared the risk consequences of fewer flights needed with the C-130, but with a larger amount of agent available for release if an accident were to occur. The subsequent campaign accident frequency for using the C-130 was less than that for the C-12, typically by two orders of magnitude. The end result is to take the frequency category to a lower level (from B [Unlikely] to C [Extremely Unlikely]) for the worst-case scenarios. However, even though the hazard distances for the C-130 loading could be as high as 10 times that of the C-12 (with factors of 3–4 times being more typical) the overall severity category designations do not change. Thus, for site type F, the risk falls in the intermediate group (from upper group using the C-12 cargo plane). The risk group assignments do not change for the other site types.

Based on the magnitude of the differences in campaign frequency and hazard distance between the two options, it is not appropriate to make a general conclusion as to preference. Rather, each option should be evaluated on a site-specific basis when military air transport of chemical munitions is being considered.

D.11 Uncertainties Associated with Accident Risk Assessment

There are inherent uncertainties associated with the risk results presented in this report. They stem primarily from the data and assumptions used in the assessment. However, the nature of the approach (i.e., bounding analysis) used to evaluate the risks associated with the unit operations is such that these uncertainties can only be addressed in qualitative terms. Nevertheless, it is still important to identify the key parameters used in the assessment that are highly uncertain (or at least more difficult to estimate at this time) and to determine how changing the default values (i.e., by lowering or increasing the estimates) could change the overall risk ranking of a particular unit operation

The key uncertain parameters that have been identified are: (a) probability of detonating an unsafe munition; (b) cleanup time in case of a spill (evaporative release); (c) response time to an instantaneous release resulting from a detonation; (d) error rate in identifying an unsafe munition; and (e) failure of the EDS vessel to contain a vapor release.

D.11.1 Effect of Munition Detonation Probability

The accident risk assessment assumes that the probability that an unsafe munition detonates when dropped is 0.4. Increasing the detonation probability from 0.4 to 1.0, would not change the estimated frequency categories; hence, the risk categories remain unchanged.

D.11.2 Effect of Cleanup Time for Spills Due to Internal Events

Accident scenarios involving treatment in the EDS that lead to spills assume a cleanup time of 15 minutes because workers are already in personal protective equipment (PPE). Cleanup times of one hour (60 min) and 4 hours (240 min) were considered. For the scenario involving a GB release (site type H), a cleanup time of 4 hours would increase the "no deaths" hazard distance to about 1,200 meters (from about 270 meters). This changes the severity category from II to I if the controlled area is limited to a 1,000-meter radius. This in turn changes the risk designation from intermediate to upper risk group for this unit operation.

Changing the cleanup time in the accident scenario involving the spill of a munition containing HD during EDS operations to 1 hour has very little effect on the "no deaths" distance. However, it would increase "no effects" distance to 275 meters (from 122 meters). A cleanup time of 4 hours increases the "no effects" distance to about 610 meters (from 122 meters). As a result, the severity category is changed from III to II for a 200-meter radius controlled area. The risk designation for the 200-meter controlled area goes from intermediate to upper risk group, but remains the same (intermediate) for the 1,000- and 2,000-meter controlled areas.

D.11.3 Response Time for Cleanup of Spills Due to External Events

The default response time for a release caused either by an external event is 4 hours. The effects of assuming response times of 8 hours and 24 hours were evaluated for scenarios involving an earthquake in the MMD-1 at site type C, and in the MMD-2 while site type E CWM are being processed. As these two scenarios involve HD spill, the 24-hour response time indicates a marked increase in the "no deaths" and "no effects" hazard distances (for the first scenario, these distances are about 1,400 meters and >10,000 meters, respectively). For these two scenarios, a 24-hour response time would change the severity category from II to I if the controlled area is limited to a 1,000-meter radius. This in turn changes the risk designation from lower to intermediate risk group.

D.11.4 Uncertainty in the Identification Error Rate

The probability that an explosively-configured munition turns out to be unsafe to handle is assumed to be 5×10^{-4}. It would take two orders of magnitude increase in the error probability to change the frequency category designation from C to B, which in turn, would raise the risk designation for site type F (for MMD-2 and EDS treatment) from the intermediate to upper risk group.

D.11.5 Uncertainty in the Failure Probability of the EDS Vessel

Testing of the prototype EDS is ongoing. At the present time, internal events leading to agent release after the munition has been placed in the EDS vessel are difficult to quantify

with a reasonable degree of confidence. In the absence of detailed design information and manufacturing requirements on equipment for the EDS and in the absence of a reasonable database of industry experience related to its use, the assessment had to rely on engineering judgment and on qualitative comparison to related accident scenarios (such as munition handling accidents) that are better characterized and which would be expected to have similar consequences. Prior to deployment of the EDS at a specific site, failure of the EDS vessel to contain agent vapor must be addressed in more detail in a site-specific accident risk assessment.

D.12 Conclusions

The major conclusions derived from this study are as follows:

- **For the preferred alternative, some unit operations have risks that are relatively higher than those associated with the no-action alternative.** Higher risks result primarily from handling and transport operations. If the no-action alternative was adopted, the public would be exposed to storage risks over a longer period of time, especially because of the uncertainty in how soon alternative technologies would be developed and deployed. Furthermore, risk from the handling and transport unit operations would not change regardless of the specific system selected to treat the CWM.

- **Accidents involving the air transport of munitions with explosives fall in the upper risk group. This unit operation applies both to the preferred and the no-action alternatives if these munitions are treated or stored at another location.** For the no-action alternative, it is also conceivable that recovered CWM items that have been transported for off-property storage could be transported to still another location for treatment. Although not analyzed in this study, this possibility represents an additional risk for the no-action alternative.

- **Treatment of an armed fuzed munition falls in the upper risk group.** As would be expected, treatment of an unsafe munition poses a higher risk. However, this does not preclude the continued development and eventual deployment of the EDS because storage of such munitions is not an option, and treatment in the EDS is a far safer method than destruction by open burning and open detonation.

- **Treatment of 155-mm projectiles with GB in the EDS falls in the upper risk group.** The risk is due to accidents that occur prior to actual treatment in the explosion containment vessel. Moreover, measures to mitigate the risk could be adopted. Therefore, this does not preclude continued development and future use of the EDS to process certain types of CWM.

- **Accidents that fall in the upper risk group category require mitigation either through improved design, enhanced training, or emergency preparedness.** While potential risk mitigation measures have been identified, they should be considered only in general terms, as actual risk mitigation measures should be developed on a site-specific basis once a site-specific accident risk assessment has been performed. The detailed site-specific analyses should be tiered to this generic assessment, and the results should be used to guide future risk management decisions.

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Appendix E

Human Toxicity of Non-Stockpile Chemicals

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Appendix E

Human Toxicity of Non-Stockpile Chemicals

This appendix summarizes the possible human health effects of chemical warfare agents and industrial chemicals likely to be encountered in items processed during the Non-Stockpile Chemical Materiel Project and chemicals used to treat these agents and industrial chemicals (see Table 1-2, Section 1-5). The information presented is for the following types of effects:

Eye and Skin Toxicity—A description of the local ocular and dermal toxicity associated with exposure to the chemical.

Inhalation Effects—A description of the toxic effects associated with inhalation of the chemical.

Systemic Effects—A description of the systemic toxicity associated with exposure to the chemical. This description includes effects seen after both short-term and long-term exposures.

Mutagenesis and Carcinogenesis—A discussion regarding the potential carcinogenicity in humans associated with exposure to the chemical.

Reproductive and Developmental Toxicity—A discussion of the potential reproductive and developmental toxicity in humans associated with exposure to the chemical.

Exposure-Response Data and Standards—An inventory of the estimated concentrations of the chemical associated with various toxicological endpoints. In addition, a listing of the various exposure limits for the chemical set by certain regulatory agencies and other bodies in the United States. When available, the following exposure-response data and standards are tabulated for each chemical: median lethal doses (LD_{50}s), median lethal concentrations (LC_{50}s), median incapacitating concentrations (IC_{50}s), the threshold limit value (TLV), permissible exposure levels (PELs), airborne exposure limits (AELs), reference doses (RfDs), reference concentrations (RfCs), the cancer slope factor (SF) and unit risk, the emergency response planning guideline concentration (ERPG-1), the temporary emergency exposure limit (TEEL-1), and the immediately dangerous to life and health concentration (IDLH).

The information contained in the following descriptions is primarily based on readily available technical literature that has been published by the Department of Defense and associated organizations. As appropriate, information from the open literature has been used to supplement this base of knowledge.

E.1 Chemical Warfare Agents

Chemical warfare agents are toxic compounds that were developed and manufactured specifically to be used by the military to kill, seriously injure, or incapacitate enemy soldiers through their physiological effects. These agents have very few, if any, other uses.

E.1.1 Lewisite (L) and Mustard-Lewisite Mixture (HL)

Lewisite and mustard-lewisite mixture are classified as blistering agents but can produce systemic effects as well. Additionally, some of the hydrolysis products of lewisite may act as blistering agents. The predominant routes of exposure are contact with the eyes and skin and inhalation of the vapor phase. The various symptoms associated with exposure to these chemicals range in severity and time of appearance during the course of exposure from blistering effects to irritation of the respiratory tract to systemic poisoning and fatality.

E.1.1.1 Eye and Skin Toxicity

Ocular exposure to lewisite causes searing pain, conjunctivitis, and inflammation of the eyes, followed by possible corneal scarring and inflammation of the iris. Mild exposure produces reversible eye damage if decontaminated instantly. Permanent injury or blindness due to corneal necrosis is possible if treatment is not immediate. Exposure of eyes to mustard-lewisite mixture vapors produces lacrimation and photophobia as well as inflammation of the conjunctiva and cornea. Exposure of the skin to lewisite or mustard-lewisite mixture may produce symptoms similar to those associated with second or third degree burns. Immediate stinging pain occurs, which increases in severity with time. Erythema appears within 30 minutes of exposure, followed by blistering within 4 to 24 hours after exposure. These blisters typically rupture and seep by 48 hours after initial exposure. Tender skin, mucous membranes, and perspiration-covered skin are highly sensitive to these agents. Clothing and immediate decontamination measures help to limit the severity of symptoms experienced.

E.1.1.2 Inhalation Effects

Inhaled lewisite is irritating to nasal passages and produces a burning sensation, followed by profuse nasal secretions and violent sneezing; prolonged exposure may result in pulmonary edema and chronic bronchitis. Inhalation of mustard-lewisite mixture results in inflammation of the upper respiratory tract, accompanied by sneezing, coughing, bronchitis, and possible pulmonary edema.

E.1.1.3 Systemic Effects

Inhalation is the main route of absorption into the body for lewisite and mustard-lewisite mixture. However, significant dermal absorption of these chemicals may occur due to their high lipid solubility. Systemic effects related to lewisite exposure include pulmonary edema, diarrhea, restlessness, weakness, abnormal body temperature, and low blood pressure. In nonfatal cases, rupture of red blood cells has occurred, resulting in hemolytic anemia. Excretion of oxidized lewisite products may contribute to damage of the liver, gall bladder, and bile ducts. In cases of high dose exposures, damage to the kidneys and urinary bladder may occur as well. In addition to its vesicant action, mustard-lewisite mixture acts as an alkylating agent and is cytotoxic to the blood-forming tissues (bone marrow, spleen, and lymph nodes). Diarrhea and fever are also associated with the systemic toxicity of mustard-

lewisite mixture. Fatality due to shock is possible following high level exposures to both lewisite and mustard-lewisite mixture.

E.1.1.4 Mutagenesis and Carcinogenesis

Available scientific data indicate that lewisite is not mutagenic. Furthermore, limited data suggest that this chemical is not carcinogenic to humans. However, some of the lewisite combustion products (arsenic trichloride, arsenic trioxide, and vinyl chloride) are known to be human carcinogens. Distilled sulfur mustard, a component of mustard-lewisite mixture, is highly mutagenic and has been classified as a human carcinogen.

E.1.1.5 Reproductive and Developmental Toxicity

Although no information is available concerning the reproductive toxicity of lewisite or mustard-lewisite mixture in humans, limited data indicate that these chemicals are not teratogenic in animals. However, distilled sulfur mustard, a component of mustard-lewisite mixture, inhibits the production of sperm in animals and possibly in humans as well.

E.1.1.6 Exposure-Response Data and Standards

LC_{50}	1200-1500 mg-min/m^3 (L; inhalation)	U.S. Army CHPPM, 1996
	1500 mg-min/m^3 (HL; inhalation)	U.S. Army CHPPM, 1996
	1500 mg-min/m^3 (L; dermal)	U.S. Army CHPPM, 1996
	10,000 mg-min/m^3 (HL; dermal)	U.S. Army CHPPM, 1996
IC_{50}	>1500 mg-min/m^3 (L; dermal)	U.S. Army CHPPM, 1996
	1500-2000 mg-min/m^3 (HL; dermal)	U.S. Army CHPPM, 1996
	300 mg-min/m^3 (L; ocular)	U.S. Army CHPPM, 1996
	200 mg-min/m^3 (HL; ocular)	U.S. Army CHPPM, 1996
AEL	3 μg/m^3 ceiling (L)	U.S. Army, 1997
RfD	0.1 μg/kg/day (L; oral)	U.S. Army CHPPM, 1999
	0.86 μg/kg/day (L; inhalation)	U.S. Army CHPPM, 1999

E.1.1.7 References

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E.1.2 Sulfur Mustards (H, HD, HT)

The sulfur mustards are toxic to humans via inhalation, ingestion, and direct contact with skin and eyes. Chemicals in this class have a similar spectrum of toxic effects but differ slightly in their potency and rapidity of onset of effects. The sulfur mustards are slowly detoxified in the body. Therefore, repeated or prolonged exposures are assumed to result in cumulative toxicity. Additionally, a delay exists between the time of exposure to sulfur mustards and the onset of symptoms. This latency period is inversely related to the degree of exposure. These chemicals can be insidious, causing damage well before the individual knows that he or she has been exposed and can take decontamination measures.

E.1.2.1 Eye and Skin Toxicity

The eye is the organ most sensitive to exposure to sulfur mustard vapor. Ocular effects usually precede effects to the skin or respiratory system. Ocular symptoms of exposure include lacrimation, pain, photophobia, conjunctivitis, inflammation of the cornea and iris, involuntary blinking, blurring of vision, and, at higher levels of exposure, mucus discharge. If the level of exposure is significant, permanent eye damage and blindness may occur due to corneal necrosis and scarring. Dermal symptoms appear 4 to 16 hours after moderate exposures. Erythema develops, accompanied by itching and irritation. These effects are followed by blister formation. Tender skin, mucous membranes, and perspiration-covered skin are particularly sensitive to sulfur mustards. Furthermore, humid conditions may increase the severity of dermal symptoms. Repeated exposures may cause dermal hypersensitivity.

E.1.2.2 Inhalation Effects

Indications of respiratory tract toxicity following inhalation of sulfur mustard vapors may include coughing, hoarseness, difficulty breathing, inflammation of the respiratory passages, development of moist rales, and possible bronchopneumonia accompanied by fever. These symptoms are delayed following exposure and typically increase in severity over several days.

E.1.2.3 Systemic Effects

Acute systemic effects are only likely to be observed in cases of severe exposure. Symptoms include decreased appetite, nausea, vomiting, diarrhea, and malaise. Fever and depression may also occur. These effects usually become apparent 4 to 16 hours after exposure and may persist for days or weeks afterward. In addition to the vesicant action of the sulfur mustards, these chemicals are highly cytotoxic to blood-forming tissues (bone marrow, spleen, and lymph nodes) due to their alkylating properties. As a result, severe anemia, decreased white blood cell counts, and increased susceptibility to infection may occur.

E.1.2.4 Mutagenesis and Carcinogenesis

Sulfur mustards are highly mutagenic agents. Furthermore, there are sufficient human and animal data to indicate that repeated exposure to sulfur mustard is associated with cancers of the respiratory tract and possibly with cancers of the skin. The International Agency for Research on Cancer has classified the sulfur mustards as known human carcinogens.

E.1.2.5 Reproductive and Developmental Toxicity

There are limited data on the reproductive and developmental toxicity of sulfur mustards in humans. These chemicals are not teratogenic in animals. However, due to their alkylating properties, the sulfur mustards inhibit the production of sperm in animals and possibly in humans. As such, these chemicals should be considered to be possible reproductive toxicants.

E.1.2.6 Exposure-Response Data and Standards

LC_{50}	1500 mg-min/m^3 (H, HD)	U.S. Army CHPPM, 1996
LD_{50}	100 mg/kg (H, HD; dermal)	U.S. Army CHPPM, 1996
	0.7 mg/kg (H, HD; oral)	U.S. Army CHPPM, 1996
IC_{50}	1500 mg-min/m^3 (H, HD; inhalation)	U.S. Army CHPPM, 1996
	1000-2000 mg-min/m^3 (HD; dermal)	U.S. Army CHPPM, 1996
	200 mg-min/m^3 (H, HD; ocular)	U.S. Army CHPPM, 1996
AEL	3 μg/m^3 ceiling (H, HD, HT)	U.S. Army, 1997
RfD	0.007 μg/kg/day (HD; oral)	U.S. Army CHPPM, 1999
	0.03 μg/kg/day (HD, inhalation)	U.S. Army CHPPM, 1999
Cancer SF	7.7 (mg/kg/day)$^{-1}$ (HD; oral)	U.S. Army CHPPM, 1999
	300 (mg/kg/day)$^{-1}$ (HD; inhalation)	U.S. Army CHPPM, 1999
TEEL-1	0.0025 mg/m^3 (HD)	U.S. DOE, 1999

E.1.2.7 References

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E.1.3 Nitrogen Mustards (HN-1, HN-2, HN-3)

The nitrogen mustards are toxic via inhalation, ingestion, and direct contact to skin and eyes. HN-1, HN-2, and HN-3 have similar spectra of toxicity, but differ slightly in their potencies and rapidity of onset of effects. The nitrogen mustards are not detoxified in the body. Therefore, repeated or prolonged exposures are assumed to result in cumulative toxicity.

E.1.3.1 Eye and Skin Toxicity

Exposure to the nitrogen mustards is irritating to the eyes, even at low concentrations which do not cause other toxic effects. Action on the eyes is extremely rapid. Mild or moderate exposures cause slight stinging of the eyes, lacrimation, and photophobia within 20 minutes. High-dose exposures may cause corneal necrosis and blindness. Mild exposure to nitrogen mustard vapors may not produce skin lesions. However, after more severe vapor exposures, or after exposure to liquid nitrogen mustards, erythema may develop within 1 hour, accompanied by itching and irritation of the contacted areas. Blisters generally appear 6-12 hours following exposure. Tender skin, mucous membranes, and perspiration-covered skin are particularly sensitive to the nitrogen mustards. Repeated exposures may result in dermal hypersensitivity.

E.1.3.2 Inhalation Effects

Respiratory symptoms of exposure to nitrogen mustards include irritation of the nose and throat, cough, and hoarseness, progressing to a loss of speech. Fever, difficulty breathing, and moist rales may develop, along with possible bronchopneumonia within the first 24 hours of exposure. In cases of high level exposures, respiratory distress may be fatal. Chronic low dose exposures may result in a persistent cough, shortness of breath, and chronic chest pain.

E.1.3.3 Systemic Effects

Systemic effects generally result from inhalation of the nitrogen mustards. In addition to their vesicant properties, the nitrogen mustards may also act as alkylating agents and be cytotoxic to blood-forming tissues (bone marrow, lymph nodes, and spleen), causing severe anemia, decreased white blood cell counts, and increased susceptibility to infection. Ingestion of nitrogen mustards causes nausea, vomiting, bloody diarrhea, and tissue damage to the gastrointestinal tract.

E.1.3.4 Mutagenesis and Carcinogenesis

Nitrogen mustards are considered by the International Agency for Research on Cancer to be human carcinogens. Although human data are limited, animal data are sufficient to suggest that nitrogen mustards are carcinogenic to humans. In addition, studies have shown that nitrogen mustards may damage DNA as a result of their alkylating properties.

E.1.3.5 Reproductive and Developmental Toxicity

There are limited data on the reproductive or developmental effects associated with nitrogen mustards exposure in humans. However, experimental research indicates that nitrogen mustards are teratogenic and can cause adverse reproductive effects in animals. Furthermore, these chemicals adversely affect human reproductive abilities by interfering with sperm production.

E.1.3.6 Exposure-Response Data and Standards

LC_{50}	1500 mg-min/m^3 (HN-1, HN-3)	U.S. Army CHPPM, 1996
	3000 mg-min/m^3 (HN-2)	U.S. Army CHPPM, 1996
	20,000 (HN-1; dermal; vapor)	U.S. Army CHPPM, 1996
	10,000 (HN-3;dermal)	U.S. Army CHPPM, 1996
LD_{50}	10 mg/kg (HN-3; dermal)	U.S. Army, 1995
IC_{50}	200 mg-min/m^3 (HN-1, ocular)	U.S. Army CHPPM, 1996
	100 mg-min/m^3 (HN-2, ocular)	U.S. Army CHPPM, 1996
	200 mg-min/m^3 (HN-3, ocular)	U.S. Army CHPPM, 1996
	9000 mg-min/m^3 (HN-1, dermal)	U.S. Army CHPPM, 1996
	9500 mg-min/m^3 (HN-2, dermal)	U.S. Army CHPPM, 1996
	2500 mg-min/m^3 (HN-3, dermal)	U.S. Army CHPPM, 1996
	35 mg-min/m^3 (dermal)	U.S. Army CHPPM, 1996
TEEL-1	4 mg/m^3 (HN-2)	U.S. DOE, 1999

E.1.3.7 References

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E.1.4 Sarin (GB)

Sarin inhibits acetylcholinesterase, an enzyme involved in the degradation of the neurotransmitter acetylcholine. This inhibition results in the accumulation of acetylcholine within the nerve synapses which, in turn, stimulates both the peripheral and central nervous systems. Life-threatening concentrations of sarin may be only slightly greater than concentrations producing minimal effects. In addition, sarin is slowly detoxified in the body. Therefore, repeated or prolonged exposures are assumed to result in cumulative toxicity.

E.1.4.1 Eye and Skin Toxicity

Sarin does not directly injure the eyes or skin. However, due to its high lipid solubility, sarin is easily absorbed following exposure by these routes.

E.1.4.2 Inhalation Effects

Sarin does not cause direct injury to the respiratory system after inhalation. However, due to its high lipid solubility, sarin is easily absorbed following exposure by this route.

E.1.4.3 Systemic Effects

Exposure to sarin inhibits acetylcholinesterase activity. The major effects of exposure include muscle twitches, tremors, weakness, runny nose, sinus congestion, drooling and excessive sweating, tightness in the chest, difficulty breathing, miosis and visual effects, headache, nausea, vomiting, abdominal cramps, and involuntary defecation and urination. Fatal doses may cause convulsions, followed by central nervous system depression, respiratory failure, and death. In cases of nonfatal exposures, many of these effects are reversible upon recovery. Scientific data suggest that chronic low-dose exposure to sarin may cause abnormalities in the electrical activity of the brain. However, the physiological consequences of this effect are not known.

E.1.4.4 Mutagenesis and Carcinogenesis

Scientific data suggest that sarin is not mutagenic and this chemical is not considered to be a human carcinogen.

E.1.4.5 Reproductive and Developmental Toxicity

No data are available regarding the reproductive or developmental toxicity of sarin in humans. However, in a limited number of studies, this chemical has been shown not to affect the reproductive ability of animals and not to be developmentally toxic in animals.

E.1.4.6 Exposure-Response Data and Standards

LC_{50}	70 mg-min/m^3	U.S. Army CHPPM, 1996
LD_{50}	24 mg/kg (dermal)	U.S. Army CHPPM, 1996
IC_{50}	35 mg-min/m^3 (inhalation)	U.S. Army, 1995
	35 mg-min/m^3 (dermal)	U.S. Army CHPPM, 1996
AEL	0.03 μg/m^3 ceiling	U.S. Army, 1997
RfD	0.02 μg/kg/day (oral)	U.S. Army CHPPM, 1999
	0.0009 μg/kg/day (inhalation)	U.S. Army CHPPM, 1999

TEEL-1	0.0075 mg/m^3	U.S. DOE, 1999
IDLH	0.2 mg/m^3	U.S. Army, 1996

E.1.4.7 References

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E.1.5 Soman (GD)

Soman inhibits acetylcholinesterase, an enzyme involved in the degradation of the neurotransmitter acetylcholine. This inhibition results in the accumulation of acetylcholine within the nerve synapses which, in turn, stimulates both the peripheral and central nervous systems. Life-threatening concentrations of soman may be only slightly greater than concentrations producing minimal effects.

E.1.5.1 Eye and Skin Toxicity

Soman does not directly injure the eyes or skin. However, due to its high lipid solubility, soman is easily absorbed following exposure by these routes.

E.1.5.2 Inhalation Effects

Soman does not cause direct injury to the respiratory system upon inhalation. However, due to its high lipid solubility, soman is easily absorbed following exposure by this route.

E.1.5.3 Systemic Effects

Exposure to soman inhibits acetylcholinesterase activity. The major effects of exposure include muscle twitches, tremors, weakness, runny nose, sinus congestion, drooling and excessive sweating, tightness in the chest, difficulty breathing, miosis and visual effects, headache, nausea, vomiting, abdominal cramps, and involuntary defecation and urination. Fatal doses may cause convulsions, followed by central nervous system depression, respiratory failure, and death. In cases of nonfatal exposures, many of these effects are reversible upon recovery.

E.1.5.4 Mutagenesis and Carcinogenesis

Scientific data suggest that soman is not mutagenic and this chemical is not considered to be a human carcinogen.

E.1.5.5 Reproductive and Developmental Toxicity

No data are available regarding the reproductive or developmental toxicity of soman in humans. However, in a limited number of studies, this chemical has been shown not to be developmentally toxic in animals.

E.1.5.6 Exposure-Response Data and Standards

LC_{50}	70 mg-min/m^3	U.S. Army CHPPM, 1996
LD_{50}	5 mg/kg (dermal)	U.S. Army CHPPM, 1996
IC_{50}	35 mg-min/m^3 (inhalation)	U.S. Army CHPPM, 1996
AEL	0.03 µg/m^3 ceiling	U.S. Army, 1997
RfD	0.004 µg/kg/day (oral)	U.S. Army CHPPM, 1999
	0.0003 µg/kg/day (inhalation)	U.S. Army CHPPM, 1999
IDLH	0.06 mg/m^3	U.S. Army, 1996

E.1.5.7 References

Edgewood Research, Development, and Engineering Center. 1996. Material Safety Data Sheet for Soman. Available on the Internet at www.apgea.army.mil/RDA/erdec/risk/safety/msds/gd1.html.

Mioduszewski, R.J., S.A. Ruetter, L.L. Miller, E.J. Olajos, and S.A. Thomson. 1998. Evaluation of Airborne Exposure Limits for G-Agents: Occupational and General Population Exposure Criteria. Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, MD.

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U.S. Department of the Army. 1997. Army Regulation 385-61, The Army Chemical Agent Safety Program. Washington, DC.

U.S. Departments of the Army, Navy, and Air Force. 1990. Potential Military Chemical/Biological Agents and Compounds. FM 3-9, Washington, DC.

E.1.6 Tabun (GA)

Tabun inhibits acetylcholinesterase, an enzyme involved in the degradation of the neurotransmitter acetylcholine. This inhibition results in the accumulation of acetylcholine within the nerve synapses which, in turn, stimulates both the peripheral and central nervous systems. Tabun is slowly detoxified in the body. Therefore, repeated or prolonged exposures are assumed to result in cumulative toxicity.

E.1.6.1 Eye and Skin Toxicity

Tabun does not directly injure the eyes or skin. However, due to its high lipid solubility, tabun is easily absorbed following exposure by these routes.

E.1.6.2 Inhalation Effects

Tabun does not cause direct injury to the respiratory system upon inhalation. However, due to its high lipid solubility, tabun is easily absorbed following exposure by this route.

E.1.6.3 Systemic Effects

Exposure to tabun inhibits acetylcholinesterase activity. Symptoms include runny nose, tightness in the chest, dimness of vision and miosis, difficulty breathing, excessive salivation and sweating, nausea, vomiting, abdominal cramps, involuntary defecation and urination, muscle twitching, jerking and staggering, headache, convulsions, drowsiness, and coma. Severe exposures may result in central nervous system depression, coma, respiratory failure, and death. In cases of nonfatal exposures, many of these effects are reversible upon recovery.

E.1.6.4 Mutagenesis and Carcinogenesis

Scientific data indicate that tabun is not mutagenic and this chemical is not considered to be a human carcinogen.

E.1.6.5 Reproductive and Developmental Toxicity

No data are available regarding the reproductive or developmental toxicity of tabun in humans. However, tabun has not been shown to be teratogenic in animals.

E.1.6.6 Exposure-Response Data and Standards

LC_{50}	135 mg-min/m^3	U.S. Army CHPPM, 1996
LD_{50}	14 - 15 mg/kg (dermal)	U.S. Army CHPPM, 1996
AEL	0.1 μg/m^3 ceiling	U.S. Army, 1997
RfD	0.04 μg/kg/day (oral)	U.S. Army CHPPM, 1999
	0.0009 μg/kg/day (inhalation)	U.S. Army CHPPM, 1999
IDLH	0.2 mg/m^3	U.S. Army, 1996

E.1.6.7 References

Edgewood Research, Development, and Engineering Center. 1996. Material Safety Data Sheet for Tabun. Available on the Internet at www.apgea.army.mil/RDA/erdec/risk/safety/msds/ga1.html.

Mioduszewski, R.J., S.A. Ruetter, L.L. Miller, E.J. Olajos, and S.A. Thomson. 1998. Evaluation of Airborne Exposure Limits for G-Agents: Occupational and General Population Exposure Criteria. Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, MD.

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E.1.7 VX (O-Ethyl-S-[2-diisopropylaminoethyl] methyl phosphonothiolate)

Nerve agent VX inhibits acetylcholinesterase, an enzyme involved in the degradation of the neurotransmitter acetylcholine. This inhibition results in the accumulation of acetylcholine within the nerve synapses which, in turn, stimulates both the peripheral and central nervous systems. Life-threatening concentrations of VX may be only slightly greater than concentrations that produce minimal effects.

E.1.7.1 Eye and Skin Toxicity

VX does not directly injure the eyes or skin. However, due to its high lipid solubility, VX is easily absorbed following exposure by these routes.

E.1.7.2 Inhalation Effects

VX does not cause direct injury to the respiratory system after inhalation. However, due to its high lipid solubility, VX is easily absorbed following exposure by this route.

E.1.7.3 Systemic Effects

Exposure to VX inhibits acetylcholinesterase activity. The major effects of exposure include muscle twitches, tremors, weakness, runny nose, sinus congestion, drooling and excessive sweating, tightness in the chest, difficulty breathing, miosis and visual effects, headache, nausea, vomiting, abdominal cramps, and involuntary defecation and urination. Fatal doses may cause convulsions, followed by central nervous system depression, respiratory failure, and death. In cases of nonfatal exposures, many of these effects are reversible upon recovery.

E.1.7.4 Mutagenesis and Carcinogenesis

In a limited number of studies, VX has been shown to have low to negligible mutagenic potential. Furthermore, this chemical is not considered to be a human carcinogen.

E.1.7.5 Reproductive and Developmental Toxicity

No data are available regarding the reproductive or developmental toxicity of VX in humans. However, VX has not been shown to be developmentally toxic in animals.

E.1.7.6 Exposure-Response Data and Standards

LC_{50}	30 mg-min/m^3	U.S. Army CHPPM, 1996
LD_{50}	0.142 mg/kg (dermal)	U.S. Army CHPPM, 1996
IC_{50}	25 mg-min/m^3 (inhalation)	U.S. Army CHPPM, 1996
AEL	0.01 μg/m^3 ceiling	U.S. Army, 1997
RfD	0.0006 μg/kg/day (oral)	U.S. Army CHPPM, 1999a
	0.00009 μg/kg/day (inhalation)	U.S. Army CHPPM, 1999a
RfC	0.0007 μg/m^3	U.S. Army CHPPM, 1999b
TEEL-1	0.00035 mg/m^3	U.S. DOE, 1999
IDLH	0.02 mg/m^3	U.S. Army, 1996

E.1.7.7 References

Edgewood Research, Development, and Engineering Center. 1996. Material Safety Data Sheet for VX. Available on the Internet at www.apgea.army.mil/RDA/erdec/risk/safety/msds/vx1.html.

Oak Ridge National Laboratory. 1997. Compilation of Existing Chemical Agent Guidelines. Oak Ridge, TN.

Program Manager for Chemical Demilitarization. 1988. Chemical Stockpile Disposal Program Final Programmatic Environmental Impact Statement, Volume 3, Appendices A-S. Aberdeen Proving Ground, MD.

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E.2 Industrial Chemicals

Industrial chemicals are those compounds that are manufactured for and used in normal industrial operations or research and are not developed primarily for military purposes. U.S. and foreign militaries, however, have used some industrial chemicals in chemical weapons and programs because of their properties.

E.2.1 Adamsite (DM)

Adamsite is a vomiting agent and is toxic via inhalation and ingestion. There is a latency period between the time of initial exposure and the development of associated symptoms. Adamsite is detoxified quickly in the body. As such, individuals exposed to adamsite generally recover within 30 minutes once removed from the contaminated area. Several hours may be required to recover from exposure to higher concentrations. Although adamsite is not intended to be a lethal agent, if released indoors as a vapor, it can cause serious illness or death.

E.2.1.1 Eye and Skin Toxicity

Acute exposure of the eyes can result in irritation and lacrimation. Although acute exposure is not known to cause adverse dermatological effects, chronic exposure has been associated with dermatitis, mild skin burns, and hyperpigmentation.

E.2.1.2 Inhalation Effects

Adamsite elicits effects similar to those seen after inhalation of pepper: inflammation of the upper respiratory tract and sinus congestion, uncontrollable sneezing and coughing, increased nasal secretions, and an intense burning sensation in the throat. Mild symptoms caused by exposure to lower concentrations resemble those of a severe cold.

E.2.1.3 Systemic Effects

Systemic effects occur primarily as a result of inhalation exposures. In addition to the previously mentioned symptoms, acute exposures to adamsite are accompanied by prominent nausea and vomiting. Severe headache, as well as tightness and pain in the chest may also occur. Mental depression may occur during the progression of symptoms.

E.2.1.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of adamsite.

E.2.1.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive and developmental toxicity of this chemical.

E.2.1.6 Exposure-Response Data and Standards

LC_{50}	11,000 mg-min/m^3	U.S. Army CHPPM, 1996
IC_{50}	22 - 150 mg-min/m^3	U.S. Army CHPPM, 1996

E.2.1.7 References

U.S. Army Center for Health Promotion and Preventive Medicine. 1996. Detailed and General Facts About Chemical Agents–TG 218. Technical Guide 218, U.S. Department of Army, Aberdeen Proving Ground, MD.

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E.2.2 Bromobenzyl Cyanide (CA)

Bromobenzyl cyanide is toxic following inhalation, ingestion, and dermal exposure. If released indoors, bromobenzyl cyanide can cause serious illness or death.

E.2.2.1 Eye and Skin Toxicity

Bromobenzyl cyanide is a mild skin irritant. Acute ocular exposure commonly results in lacrimation.

E.2.2.2 Inhalation Effects

Acute inhalation of bromobenzyl cyanide may result in a burning sensation in the mouth and throat.

E.2.2.3 Systemic Effects

Systemic effects following dermal exposure or inhalation include intense headache, cyanosis, anxiety and agitation, and nausea.

E.2.2.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of bromobenzyl cyanide.

E.2.2.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.2.2.6 Exposure-Response Data and Standards

LC_{50}	8000-11,000 mg-min/m^3 (est.)	U.S. Army CHPPM, 1996
IC_{50}	30 mg-min/m^3	U.S. Army CHPPM, 1996

E.2.2.7 References

U.S. Army Center for Health Promotion and Preventive Medicine. 1996. Detailed and General Facts About Chemical Agents–TG 218. Technical Guide 218, U.S. Department of the Army, Aberdeen Proving Ground, MD.

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U.S. Departments of the Army, Navy, and Air Force. 1990. Potential Military Chemical/Biological Agents and Compounds. FM 3-9, Washington, DC.

E.2.3 Chloroacetophenone (CN)

Chloroacetophenone is classified as a lacrimator, although it may also produce respiratory and systemic effects. It is toxic following inhalation, ingestion, and contact with skin and eyes. Exposure to high concentrations of chloroacetopheneone within a confined space may be fatal.

E.2.3.1 Eye and Skin Toxicity

Contact with chloroacetophenone may cause irritation to the eyes and skin. Chloroacetophenone is a strong lacrimator, and exposure to high concentrations produces burning and pain in the eyes, blurred vision, marked conjunctivitis, and may cause corneal damage. In general, effects of dermal exposure to chloroacetophenone are similar to those produced by sunburn and disappear within a few hours. Chloroacetophenone is especially irritating to moist skin. Exposures to non-intact skin or mucous membranes may result in blisters, rashes, or burns.

E.2.3.2 Inhalation Effects

Chloroacetophenone is an upper respiratory tract irritant and may cause a tingling sensation and runny nose, a burning sensation in the chest, and difficulty breathing.

E.2.3.3 Systemic Effects

Acute exposure to chloroacetophenone may result in pulmonary congestion and edema. In some instances, these effects may be fatal. If ingested, irritation and burning of the gastrointestinal tract may occur. Some individuals experience nausea following exposure to chloroacetophenone.

E.2.3.4 Mutagenesis and Carcinogenesis

No adequate data are available to assess the mutagenic or carcinogenic potential of chloroacetophenone.

E.2.3.5 Reproductive and Developmental Toxicity

No data are available to assess the reproductive or developmental effects of chloroacetophenone in humans.

E.2.3.6 Exposure-Response Data and Standards

LC_{50}	7000 mg-min/m^3	U.S. Army CHPPM, 1996
IC_{50}	80 mg-min/m^3	U.S. Army CHPPM, 1996
TLV	0.05 ppm (0.32 mg/m^3) TWA	OSHA
PEL	0.05 ppm (0.3 mg/m^3) TWA	OSHA
RfC	0.03 μg/m^3	U.S. EPA, 1998
IDLH	15 mg/m^3	NIOSH, 1998

E.2.3.7 References

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U.S. Environmental Protection Agency. 1998. Integrated Risk Information System database. Available on the Internet at www.epa.gov/iris/.

E.2.4 Chloroacetophenone in Benzene and Carbon Tetrachloride (CNB)

Please refer to the sections of Appendix E that describe the human toxicity associated with exposure to chloroacetophenone (E.2.3), benzene (E.2.13), and carbon tetrachloride (E.2.14).

E.2.5 Chloroacetophenone and Chloropicrin in Chloroform (CNS)

Please refer to the sections of Appendix E that describe the human toxicity associated with exposure to chloroacetophenone (E.2.3), chloropicrin (E.2.6), and chloroform (E.2.16).

E.2.6 Chloropicrin (PS)

Chloropicrin is toxic following inhalation, ingestion, and contact with skin and eyes.

E.2.6.1 Eye and Skin Toxicity

Chloropicrin is immediately irritating to the eyes and skin. Exposure to the eyes causes lacrimation, pain, and burning. Contact with skin is irritating and can result in blister formation.

E.2.6.2 Inhalation Effects

Inhalation is the primary exposure route of concern for chloropicrin. Chloropicrin vapor is intensely irritating to the mucous membranes and upper respiratory tract, in some cases causing bronchitis and pulmonary edema. Exposure to chloropicrin produces coughing and severe breathing difficulties that may be fatal.

E.2.6.3 Systemic Effects

Systemic symptoms typically occur following inhalation of chloropicrin and include nausea, vomiting, and cyanosis. Long-term effects associated with chloropicrin exposure include damage to the kidneys and heart, and hypersensitivity to subsequent chloropicrin exposures.

E.2.6.4 Mutagenesis and Carcinogenesis

No adequate data are available to assess the mutagenic or carcinogenic potential of chloropicrin.

E.2.6.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.2.6.6 Exposure-Response Data and Standards

LC_{50}	2000 mg-min/m^3	U.S. Army CHPPM, 1996
TLV	0.1 ppm (0.67 mg/m^3) TWA	OSHA
PEL	0.1 ppm (0.7 mg/m^3) TWA	OSHA
ERPG-1	0.1 ppm	AIHA, 1999
TEEL-1	0.2 ppm	U.S. DOE, 1999
IDLH	2 ppm	NIOSH, 1998

E.2.6.7 References

American Industrial Hygiene Association. 1999. Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook. Fairfax, VA.

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National Toxicology Program. 1978. Technical Report 65, Bioassay of Chloropicrin for Possible Carcinogenicity (CAS No. 76-06-2). Report abstract available on the Internet at ntp-server.niehs.nih.gov/.

Occupational Health and Safety Administration. Chemical Sampling Information database. Available on the Internet at www.osha-slc.gov/OCIS/toc_chemsamp.html.

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E.2.7 Cyanogen Chloride (CK)

Cyanogen chloride is toxic following inhalation, ingestion, and dermal absorption. It is converted to hydrogen cyanide in the body. However, unlike hydrogen cyanide, cyanogen chloride is a strong irritant to the eyes and respiratory tract. In addition, cyanogen chloride acts as a choking agent and makes breathing difficult.

E.2.7.1 Eye and Skin Toxicity

Cyanogen chloride is irritating to both the eyes and skin, even at low concentrations. Exposure of the eyes results in lacrimation. Dermal contact with liquid cyanogen chloride can produce severe burns. Prolonged dermal exposures may result in dermatitis.

E.2.7.2 Inhalation Effects

Inhalation of cyanogen chloride is irritating to the upper respiratory tract and lungs, even at low concentrations. Respiratory symptoms following acute exposure include coughing, difficulty breathing, tightness in the chest, the coughing up of blood, and possible pulmonary edema. In cases of severe exposure, respiratory failure and death may occur.

E.2.7.3 Systemic Effects

Systemic effects arise from the conversion of cyanogen chloride to hydrogen cyanide in the body. Symptoms include dizziness, anxiety, vertigo, retching and vomiting, and involuntary urination and defecation. More severe exposures may cause unconsciousness, convulsions, respiratory failure, and death.

E.2.7.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of cyanogen chloride.

E.2.7.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive and developmental toxicity of this chemical.

E.2.7.6 Exposure-Response Data and Standards

LC_{50}	11,000 mg-min/m^3	U.S. Army CHPPM, 1996
IC_{50}	7000 mg-min/m^3	U.S. Army CHPPM, 1996
TLV	0.3 ppm (0.75 mg/m^3) ceiling	OSHA
RfD	0.05 mg/kg/day	U.S. EPA, 1998
TEEL-1	0.06 ppm	U.S. DOE, 1999
IDLH	50 mg/m^3	U.S. Army, 1996

E.2.7.7 References

National Institute for Occupational Safety and Health. 1997. NIOSH Pocket Guide to Chemical Hazards, 97-140. U.S. Department of Health and Human Services, Washington, DC.

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U.S. Environmental Protection Agency. 1998. Integrated Risk Information System database. Available on the Internet at www.epa.gov/iris/.

E.2.8 Hydrogen Cyanide (AC)

Hydrogen cyanide acts by interfering with the body's ability to utilize oxygen and make energy. Hydrogen cyanide is toxic following inhalation, ingestion, and dermal absorption. The onset of effects is extremely rapid.

E.2.8.1 Eye and Skin Toxicity

Hydrogen cyanide does not directly injure the skin or eyes. However, this chemical can be easily absorbed through the skin in amounts significant enough to cause systemic effects.

E.2.8.2 Inhalation Effects

Inhalation of hydrogen cyanide may cause a burning sensation and some initial dryness in the throat. Severe inhalation exposures may cause respiratory failure and death. Moderate exposures may cause an increase in the breathing rate.

E.2.8.3 Systemic Effects

Systemic effects of hydrogen cyanide exposure include a reddening of the eyes and flushing of the skin, nausea and vomiting, headache, dizziness, rapid pulse, drowsiness, decreased blood pressure, weakness, and unconsciousness. Exposure to a high concentration of hydrogen cyanide may cause convulsions, respiratory failure, and death.

E.2.8.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of hydrogen cyanide.

E.2.8.5 Reproductive and Developmental Toxicity

No data are available regarding the human reproductive or developmental toxicity of this chemical. However, cyanide-containing compounds have been shown to be teratogenic in animals.

E.2.8.6 Exposure-Response Data and Standards

LC_{50}	(see below)	U.S. Army CHPPM, 1996
LD_{50}	100 mg/kg (dermal; liquid)	U.S. Army CHPPM, 1996
TLV	4.7 ppm (5 mg/m^3) ceiling	OSHA
PEL	10 ppm (11 mg/m^3) TWA	OSHA
RfD	0.02 mg/kg/day	U.S. EPA, 1998
RfC	3 μg/m^3	U.S. EPA, 1998
TEEL-1	4.7 ppm	U.S. DOE, 1999
IDLH	50 ppm	NIOSH, 1998

According to the U.S. Army, the median lethal concentration (LC_{50}) for inhalation of hydrogen cyanide varies greatly with the conditions of exposure due to the rapid detoxification rate for hydrogen cyanide in the body. For example, the LC_{50} is 2000 mg-min/m^3 for a 0.5 minute exposure and 20,600 mg-min/m^3 for a 30 minute exposure.

E.2.8.7 References

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Scialli, A.R., A. Lione, and G.K.B. Padgett. 1995. Reproductive Effects of Chemical, Physical, and Biologic Agents REPROTOX®. The Johns Hopkins University Press, Baltimore, MD.

U.S. Army Center for Health Promotion and Preventive Medicine. 1996. Detailed and General Facts About Chemical Agents–TG 218. Technical Guide 218, U.S. Department of the Army, Aberdeen Proving Ground, MD.

U.S. Department of the Army. 1974. Chemical Agent Data Sheets, Vol. I. Edgewood Arsenal Special Report EO-SR-74001, Defense Technical Information Center, Alexandria, VA.

U.S. Departments of the Army, Navy, and Air Force. 1990. Potential Military Chemical/Biological Agents and Compounds. FM 3-9, Washington, DC.

U.S. Department of Energy, Subcommittee on Consequence Assessment and Protective Actions. 1999. ERPGs and Recommended TEELs. Available on the Internet at tis.eh.doe.gov/web/chem_safety/teelintro.html.

U.S. Environmental Protection Agency. 1998. Integrated Risk Information System database. Available on the Internet at www.epa.gov/iris/.

E.2.9 Phosgene (CG) and Diphosgene (DP)

Inhalation is the most important route of exposure to phosgene and diphosgene. Phosgene is a corrosive, highly toxic gas that is poisonous if inhaled or absorbed through the skin. Diphosgene is converted to phosgene within the body. Therefore, exposure to either chemical yields similar toxic effects.

E.2.9.1 Eye and Skin Toxicity

Phosgene is a severe eye and skin irritant. Following exposure to liquid phosgene, severe dermal burns may develop. In addition, liquid phosgene can cause corneal clouding. Diphosgene is not considered a skin irritant, although some sensitization may occur on dermal contact. Exposure to diphosgene can cause eye irritation and slight lacrimation.

E.2.9.2 Inhalation Effects

The lung is the primary target for phosgene and diphosgene toxicity. Acute exposures can cause irritation of the upper respiratory tract, coughing and choking, a burning sensation in the throat, difficulty breathing, chest pain, severe (usually delayed) pulmonary edema, pneumonia, and respiratory failure. Chronic low-dose exposures may result in the development of emphysema and pulmonary fibrosis.

E.2.9.3 Systemic Effects

No data are available regarding potential systemic effects following acute exposure to diphosgene. However, studies with phosgene show that cardiac failure, resulting in death, may be a complication of the resulting pulmonary edema. Gastrointestinal symptoms of high-dose exposures include nausea and vomiting. Other systemic effects, such as cyanosis, anxiety, numbness, and headache may also occur.

E.2.9.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of these chemicals.

E.2.9.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of these chemicals.

E.2.9.6 Exposure-Response Data and Standards

LC_{50}	3200 mg-min/m^3 (CG, DP)	U.S. Army, Navy, Air Force, 1990
IC_{50}	1600 mg-min/m^3 (CG, DP; inhalation)	U.S. Army, Navy, Air Force, 1990
TLV	0.1 ppm (0.4 mg/m^3) TWA (CG)	U.S. Army, 1996
TEEL-1	0.1 ppm (CG)	U.S. DOE, 1999
IDLH	2 ppm (CG)	NIOSH, 1998

E.2.9.7 References

National Institute for Occupational Safety and Health. 1997. NIOSH Pocket Guide to Chemical Hazards, 97-140. U.S. Department of Health and Human Services, Washington, DC.

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U.S. Department of the Army. 1974. Chemical Agent Data Sheets, Vol. I. Edgewood Arsenal Special Report EO-SR-74001, Defense Technical Information Center, Alexandria, VA.

U.S. Department of the Army. 1995. Chemical Agent Identification Sets (CAIS) Information Package. Aberdeen Proving Ground, MD.

U.S. Department of the Army. 1996. Health and Safety Plan for Rapid Response System Operation at Deseret Chemical Depot, Utah. Aberdeen Proving Ground, MD.

U.S. Department of the Army. 1996. Monitoring Concept Plan, Buried Chemical Materiel, Types 1 and 2, Revision 1. Program Manager for Non-Stockpile Chemical Materiel. Aberdeen Proving Ground, MD.

U.S. Departments of the Army, Navy, and Air Force. 1990. Potential Military Chemical/Biological Agents and Compounds. FM 3-9, Washington, DC.

U.S. Department of Energy, Subcommittee on Consequence Assessment and Protective Actions. 1999. ERPGs and Recommended TEELs. Available on the Internet at tis.eh.doe.gov/web/chem_safety/teelintro.html.

U.S. Environmental Protection Agency. 1998. Integrated Risk Information System database. Available on the Internet at www.epa.gov/iris/.

E.2.10 3-Quinuclidinyl Benzilate (BZ)

BZ is toxic following inhalation, ingestion, and contact with eyes and skin. BZ depresses both the peripheral and central nervous systems by interfering with the ability of acetylcholine to transmit nerve impulses across synapses.

E.2.10.1 Eye and Skin Toxicity

Acute exposure to BZ can result in slight blurring of vision and moderate dilation of the pupils. Skin may also appear dry and flushed following exposure to BZ.

E.2.10.2 Inhalation Effects

Other than an increased rate of respiration, no other potential adverse effects to the respiratory system are known.

E.2.10.3 Systemic Effects

BZ interferes with acetylcholine activity in the central nervous system, affecting memory, orientation, problem-solving abilities, attention, and comprehension. In addition, BZ stimulates norepinephrine activity in the brain, causing delirium and vivid hallucinations. Because of its anticholinergic action, BZ may also affect circulation of the blood and digestion. Symptoms associated with anticholinergic activity include increased heart rate, increased respiration rate, decreased sweating and salivation, constipation, and decreased urination.

E.2.10.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of this chemical.

E.2.10.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.2.10.6 Exposure-Response Data and Standards

LC_{50}	200,000 mg-min/m^3	U.S. Army CHPPM, 1996
IC_{50}	101 mg-min/m^3 (ocular)	U.S. Army CHPPM, 1996
AEL	0.004 mg/m^3 TWA	U.S. Army CHPPM, 1996
IDLH	0.2 mg/m^3	U.S. Army, 1996

E.2.10.7 References

U.S. Army Center for Health Promotion and Preventive Medicine. 1996. Detailed and General Facts About Chemical Agents–TG 218. Technical Guide 218, U.S. Department of the Army, Aberdeen Proving Ground, MD.

U.S. Department of the Army. 1974. Chemical Agent Data Sheets, Vol. I. Edgewood Arsenal Special Report EO-SR-74001, Defense Technical Information Center, Alexandria, VA.

U.S. Department of the Army. 1996. Monitoring Concept Plan, Buried Chemical Materiel, Types 1 and 2, Revision 1. Program Manager for Non-Stockpile Chemical Materiel. Aberdeen Proving Ground, MD.

U.S. Departments of the Army, Navy, and Air Force. 1990. Potential Military Chemical/Biological Agents and Compounds. FM 3-9, Washington, DC.

E.2.11 GA Simulants

GA simulants may be composed of the following chemicals: diethyl malonate, ethyl heptanoate, benzonitrile, ethyl caprylate, and ethyl myristate. These chemicals are toxic following inhalation, ingestion, and dermal absorption. Data on the toxic effects of the GA simulants are extremely limited.

E.2.11.1 Eye and Skin Toxicity

Contact of the eyes and skin with the various chemical components of the GA simulants is highly irritating. Diethyl malonate may cause redness and pain to both the eyes and skin. Benzonitrile may cause burning of the eyes and lacrimation; prolonged or repeated exposure may cause dermatitis and conjunctivitis.

E.2.11.2 Inhalation Effects

The various chemical components of GA simulants are irritating to the mucous membranes and upper respiratory tract. Exposure to high concentrations of benzonitrile may cause cyanosis, shallow respiration, convulsions, collapse, and death due to respiratory arrest.

E.2.11.3 Systemic Effects

Ingestion of diethyl malonate may result in sore throat, abdominal pain, and diarrhea. Benzonitrile exposure may cause nausea, vomiting, dizziness, drowsiness, headache, weakness, confusion, and cyanosis. Severe exposures to benzonitrile may result in unconsciousness, convulsions, and fatality due to respiratory failure. No data are available to assess the systemic effects associated with exposure to the other chemical components of the GA simulants.

E.2.11.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of these chemicals. However, experimental evidence suggest that benzonitrile is not mutagenic.

E.2.11.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of these chemicals.

E.2.11.6 Exposure-Response Data and Standards

Few human exposure-response data are available for the GA simulants or their primary components.

TEEL-1	15 mg/m^3 (for benzonitrile)	U.S. DOE, 1999

E.2.11.7 References

Cornell University. 1998. Material Safety Data Sheets database. Available on the Internet at www.MSDS.PDC.CORNELL.EDU/.

U.S. Department of the Army. 1995. Chemical Agent Identification Sets (CAIS) Information Package. Aberdeen Proving Ground, MD.

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E.2.12 Triphosgene

Triphosgene is toxic following inhalation, ingestion, and dermal contact. However, little is known concerning the human toxicity of this chemical.

E.2.12.1 Eye and Skin Toxicity

Triphosgene is irritating and corrosive to both the eyes and skin. It is a strong lacrimator and can cause systemic effects if absorbed through the skin.

E.2.12.2 Inhalation Effects

High concentrations of triphosgene are extremely destructive to the mucous membranes of the upper respiratory tract. Inhalation may result in spasms, inflammation, and edema of the upper respiratory tract, pneumonitis, and pulmonary edema.

E.2.12.3 Systemic Effects

No data are available to assess the potential systemic effects resulting from exposure to triphosgene.

E.2.12.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of this chemical.

E.2.12.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.2.12.6 Exposure-Response Data and Standards

No data or standards are available for triphosgene.

E.2.12.7 References

Cornell University. 1998. Material Safety Data Sheets database. Available on the Internet at www.MSDS.PDC.CORNELL.EDU/.

U.S. Department of the Army. 1995. Chemical Agent Identification Sets (CAIS) Information Package. Aberdeen Proving Ground, MD.

E.2.13 Benzene

Benzene is toxic following inhalation, ingestion, and dermal contact.

E.2.13.1 Eye and Skin Toxicity

Benzene is irritating to the eyes and skin. Prolonged or repeated exposures may result in conjunctivitis, erythema, dermatitis, and an increased susceptibility to infections. Due to its high lipid solubility, benzene can be absorbed in significant amounts through the skin.

E.2.13.2 Inhalation Effects

Benzene is a respiratory tract irritant and may cause bronchitis. Inhalation of this chemical results in systemic effects.

E.2.13.3 Systemic Effects

Benzene exposure results in depression of the central nervous system. Systemic effects include headache, confusion, dizziness, disorientation, drowsiness, lethargy, weakness, ringing of the ears, nausea, and vomiting. Extreme exposure may result in unconsciousness, coma, and death. Benzene is also toxic to the blood-forming tissues (bone marrow, spleen, and lymph nodes) and exposure can result in anemia.

E.2.13.4 Mutagenesis and Carcinogenesis

Benzene is considered to be a human carcinogen by the International Agency for Research on Cancer. This chemical is mutagenic and causes cancer in animal studies. Furthermore, benzene exposure has been associated with an increased incidence of leukemias and myelomas in humans.

E.2.13.5 Reproductive and Developmental Toxicity

Benzene exposure has been associated with fetotoxicity and fetal growth retardations in animal studies. However, benzene has not been shown to be teratogenic.

E.2.13.6 Exposure-Response Data and Standards

TLV	0.5 ppm TWA	OSHA
	2.5 ppm STEL	OSHA
PEL	1 ppm TWA	OSHA
	5 ppm STEL	OSHA
Cancer SF	0.029 $(mg/kg/day)^{-1}$ (oral)	U.S. EPA, 1998
	0.029 $(mg/kg/day)^{-1}$ (inhalation)	U.S. EPA, 1997
Cancer unit risk	0.00000083 $(\mu g/L)^{-1}$	U.S. EPA, 1998
EPRG-1	50 ppm	AIHA, 1999
TEEL-1	50 ppm	U.S. DOE, 1999
IDLH	500 ppm	NIOSH, 1998

E.2.13.7 References

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Occupational Health and Safety Administration. Chemical Sampling Information database. Available on the Internet at www.osha-slc.gov/OCIS/toc_chemsamp.html.

Shepard, T.H. 1995. Catalog of Teratogenic Agents, Eighth Edition. The Johns Hopkins University Press, Baltimore, MD.

U.S. Department of Energy, Subcommittee on Consequence Assessment and Protective Actions. 1999. ERPGs and Recommended TEELs. Available on the Internet at tis.eh.doe.gov/web/chem_safety/teelintro.html.

U.S. Environmental Protection Agency. 1997. Health Effects Assessment Summary Tables, FY 1997 Update. Office of Research and Development, Washington, DC.

U.S. Environmental Protection Agency. 1998. Integrated Risk Information System database. Available on the Internet at www.epa/gov/iris/.

E.2.14 Carbon Tetrachloride

Carbon tetrachloride is toxic following inhalation, ingestion, and contact with eyes and skin.

E.2.14.1 Eye and Skin Toxicity

Dermal exposure to carbon tetrachloride causes pain, erythema, and blistering. Acute exposure of the eyes can cause severe irritation and burning.

E.2.14.2 Inhalation Effects

No data are available regarding the pulmonary effects of carbon tetrachloride. However, inhalation of this chemical can result in systemic effects.

E.2.14.3 Systemic Effects

Systemically, carbon tetrachloride depresses the central nervous system. Symptoms include headache, dizziness, confusion, drowsiness, nausea, and vomiting. Ability to see clearly may be diminished. Damage to the kidneys and liver may occur. In cases of extreme exposure, coma and death due to respiratory arrest or circulatory collapse may result.

E.2.14.4 Mutagenesis and Carcinogenesis

There is sufficient animal data to suggest that exposure to carbon tetrachloride may be associated with cancer of the liver. Consequently, the International Agency for Research on Cancer has classified carbon tetrachloride as a possible human carcinogen.

E.2.14.5 Reproductive and Developmental Toxicity

No data are available regarding the human reproductive or developmental effects of carbon tetrachloride. However, experimental studies have shown that carbon tetrachloride may be associated with fetotoxicity and reduced fetal growth in laboratory animals.

E.2.14.6 Exposure-Response Data and Standards

TLV	5 ppm (31 mg/m^3) TWA	OSHA
PEL	10 ppm TWA	OSHA
	25 ppm ceiling	OSHA
RfD	0.7 μg/kg/day	U.S. EPA, 1998
Cancer SF	0.13 $(mg/kg/day)^{-1}$ (oral)	U.S. EPA, 1998
	0.053 $(mg/kg/day)^{-1}$ (inhalation)	U.S. EPA, 1997
Cancer unit risk	0.0000037 $(\mu g/L)^{-1}$	U.S. EPA, 1998
EPRG-1	20 ppm	AIHA, 1999
TEEL-1	20 ppm	U.S. DOE, 1999
IDLH	200 ppm	NIOSH, 1998

E.2.14.7 References

American Industrial Hygiene Association. 1999. Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook. Fairfax, VA.

National Institute for Occupational Safety and Health. 1998. NIOSH Chemical Listing and Documentation of Revised IDLH Values (as of 3/1/95). Available on the Internet at www.cdc.gov/niosh/idlh/idlhview.html.

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E.2.15 Chlorobenzene

Chlorobenzene is toxic following inhalation, ingestion, and dermal exposure.

E.2.15.1 Eye and Skin Toxicity

Dermal contact with chlorobenzene can cause slight irritation to the skin. Prolonged or repeated exposures may cause dermatitis. Ocular contact with chlorobenzene results in burning pain and lacrimation.

E.2.15.2 Inhalation Effects

Inhalation of chlorobenzene results in irritation of the upper respiratory tract.

E.2.15.3 Systemic Effects

Systemic effects associated with inhalation or ingestion result from depression of the central nervous system and include headache, nausea, vomiting, dizziness, drowsiness, and unconsciousness. In cases of severe exposure, death may result due to respiratory failure. Chlorobenzene exposure may also cause hemolytic anemia and damage to the liver and kidneys.

E.2.15.4 Mutagenesis and Carcinogenesis

No data are available to assess the carcinogenic potential of chlorobenzene in humans. However, experimental data indicate that chlorobenzene is not mutagenic and suggest that it is not carcinogenic in animals.

E.2.15.5 Reproductive and Developmental Toxicity

No data are available regarding the human reproductive or developmental effects of chlorobenzene. However, experimental studies have shown that chlorobenzene does not cause adverse reproductive or developmental effects in laboratory animals.

E.2.15.6 Exposure-Response Data and Standards

TLV	10 ppm (46 mg/m^3) TWA	OSHA
PEL	75 ppm (350 mg/m^3) TWA	OSHA
RfD	0.02 mg/kg/day	U.S. EPA, 1998
TEEL-1	30 ppm	U.S. DOE, 1999
IDLH	1000 ppm	NIOSH, 1998

E.2.15.7 References

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National Library of Medicine. 1998. Hazardous Substances Database, Toxicology Data Network. Available on the Internet at www.toxnet.nlm.nih.gov/serlets/simple-search.

National Toxicology Program. 1985. Technical Report 261, Toxicology and Carcinogenesis Studies of Chlorobenzene (CAS No. 108-90-7) in F344/N Rats and $B6C3F_1$ Mice (Gavage Studies). Report abstract available on the Internet at ntp-server.niehs.nih.gov/.

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U.S. Environmental Protection Agency. 1998. Integrated Risk Information System database. Available on the Internet at www.epa/gov/iris/.

E.2.16 Chloroform

Chloroform is toxic following inhalation, ingestion, and dermal and ocular exposures.

E.2.16.1 Eye and Skin Toxicity

Contact with chloroform is irritating to the eyes and skin. Ocular contact with chloroform causes immediate burning, pain, lacrimation, and conjunctivitis. Irreversible eye damage may result. Dermal contact can cause mild irritation, itching, and erythema. Prolonged or repeated exposures may cause dermatitis. Significant dermal absorption of chloroform is possible.

E.2.16.2 Inhalation Effects

Inhalation of chloroform is irritating to the upper respiratory tract and may cause dryness of the mouth and throat.

E.2.16.3 Systemic Effects

Systemic effects may result from inhalation, ingestion, and dermal absorption of chloroform. Symptoms result from depression of the central nervous system and include headache, dizziness, drowsiness, nausea, vomiting, muscle incoordination, unconsciousness, and possible fatality due to respiratory failure or cardiac arrest. Delayed effects of exposure to high concentrations of chloroform include severe damage to the liver, kidneys, and heart. Chronic low-dose exposures may cause headache, mental confusion, depression, fatigue, loss of appetite, nausea, vomiting, chronic cough, and loss of balance.

E.2.16.4 Mutagenesis and Carcinogenesis

Chloroform has been shown to be mutagenic and has been classified as a probable human carcinogen.

E.2.16.5 Reproductive and Developmental Toxicity

No data are available regarding the human reproductive and developmental toxicity of chloroform. However, experimental animal data suggest that chloroform is not teratogenic in the absence of overt maternal toxicity.

E.2.16.6 Exposure-Response Data and Standards

TLV	10 ppm (49 mg/m^3) TWA	OSHA
PEL	50 ppm (240 mg/m^3) ceiling	OSHA
RfD	0.01 mg/kg/day	U.S. EPA, 1998
RfC	3.50 $\mu g/m^3$	U.S. Army CHPPM, 1999
Cancer SF	0.0061 $(mg/kg/day)^{-1}$ (oral)	U.S. EPA, 1998
	0.081 $(mg/kg/day)^{-1}$ (inhalation)	U.S. EPA, 1997
Cancer unit risk	0.00000017 $(\mu g/L)^{-1}$	U.S. EPA, 1998
TEEL-1	2 ppm	U.S. DOE, 1999
IDLH	500 ppm	NIOSH, 1998

E.2.16.7 References

Fisher Chemical Company. Catalog and Material Safety Data Sheets. Available on the Internet at www.fisher1.com.

National Institute for Occupational Safety and Health. 1997. NIOSH Pocket Guide to Chemical Hazards, 97-140. U.S. Department of Health and Human Services, Washington, DC.

National Institute for Occupational Safety and Health. 1998. NIOSH Chemical Listing and Documentation of Revised IDLH Values (as of 3/1/95). Available on the Internet at www.cdc.gov/niosh/idlh/idlhview.html.

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Scialli, A.R., A. Lione, and G.K.B. Padgett. 1995. Reproductive Effects of Chemical, Physical, and Biologic Agents REPROTOX®. The Johns Hopkins University Press, Baltimore, MD.

U.S. Army Center for Health Promotion and Preventive Medicine. 1999. Preliminary Assessment of Health impacts for the Newport Chemical Agent Disposal Facility, Newport, Indiana. Aberdeen Proving Ground, MD.

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E.2.17 Nitrobenzene

Nitrobenzene is toxic following inhalation, ingestion, and dermal absorption.

E.2.17.1 Eye and Skin Toxicity

Eyes may lacrimate and develop a brownish discoloration over time. Dermal contact with nitrobenzene may cause the skin to become irritated and inflamed. Nitrobenzene is rapidly absorbed through the skin. Chronic exposures to nitrobenzene may be associated with conjunctivitis and dermatitis.

E.2.17.2 Inhalation Effects

Inhalation of nitrobenzene is moderately irritating to the upper respiratory tract and may result in systemic effects.

E.2.17.3 Systemic Effects

Nitrobenzene interferes with oxygen transport by red blood cells. Systemic effects resulting from nitrobenzene exposure include headache, difficulty breathing, low blood pressure, cyanosis, nausea, vomiting, dizziness, drowsiness, confusion, weakness, and convulsions. Death may occur as a result of respiratory failure. In nonfatal cases, damage to the liver, kidneys, and blood-forming tissues (bone marrow, lymph nodes, and spleen) may result.

E.2.17.4 Mutagenesis and Carcinogenesis

Nitrobenzene has been shown to have low to negligible mutagenic activity. However, experimental data suggest that this chemical is carcinogenic to animals. Furthermore, nitrobenzene has been classified as a human carcinogen.

E.2.17.5 Reproductive and Developmental Toxicity

No data are available regarding the human reproductive or developmental toxicity of nitrobenzene. While nitrobenzene is not teratogenic in experimental animals, exposure to this chemical has been shown to inhibit sperm production.

E.2.17.6 Exposure-Response Data and Standards

TLV	1 ppm (5 mg/m^3) TWA	OSHA
PEL	1 ppm (5 mg/m^3) TWA	OSHA
RfD	0.5 µg/kg/day	U.S. EPA, 1998
TEEL-1	3 ppm	U.S. DOE, 1999
IDLH	200 ppm	NIOSH, 1998

E.2.17.7 References

Cornell University. 1998. Material Safety Data Sheets database. Available on the Internet at www.MSDS.PDC.CORNELL.EDU/.

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E.3 Treatment Chemicals

Treatment chemicals are those chemicals that would be added to chemical warfare agents and sometimes to the industrial chemical phosgene as treatment reagents to neutralize the lethal properties of the agents.

E.3.1 Monoethanolamine (MEA)

MEA is toxic following inhalation, ingestion, and contact with skin and eyes.

E.3.1.1 Eye and Skin Toxicity

MEA in high concentrations may cause severe irritation or burns to the eyes and skin. Pre-existing skin damage may be aggravated by exposure. MEA may be absorbed in significant amounts through the skin.

E.3.1.2 Inhalation Effects

Inhalation of MEA may cause severe irritation to the mucous membranes and upper respiratory tract. Respiratory symptoms associated with exposure to high levels of MEA include a burning sensation in the throat, coughing, and wheezing. Exposures to MEA may also aggravate pre-existing asthma and pulmonary conditions.

E.3.1.3 Systemic Effects

Ingestion of MEA causes nausea, vomiting, gastrointestinal irritation and burning, and abdominal pain. Systemic effects result from depression of the central nervous system and are characterized by headache and lethargy. Chronic low-dose exposure may cause damage to the liver and kidneys.

E.3.1.4 Mutagenesis and Carcinogenesis

Data suggest that MEA is not a human carcinogen.

E.3.1.5 Reproductive and Developmental Toxicity

Data suggest that MEA is not a human reproductive or developmental toxicant.

E.3.1.6 Exposure-Response Data and Standards

TLV	3 ppm (7.5 mg/m^3) TWA	OSHA
	6 ppm (15 mg/ m^3) STEL	OSHA
PEL	3 ppm (6 mg/m^3) TWA	OSHA
TEEL-1	6 ppm	U.S. DOE, 1999
IDLH	30 ppm	NIOSH, 1998

E.3.1.7 References

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U.S. Department of Energy, Subcommittee on Consequence Assessment and Protective Actions. 1999. ERPGs and Recommended TEELs. Available on the Internet at tis.eh.doe.gov/web/chem_safety/teelintro.html.

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E.3.2 1,3-Dichloro-5,5-Dimethylhydantoin (DCDMH)

Limited human toxicity data are available for DCDMH.

E.3.2.1 Eye and Skin Toxicity

Dermal and ocular exposures to DCDMH result in marked irritation at the area of contact.

E.3.2.2 Inhalation Effects

Inhalation of DCDMH causes extreme irritation of the mucous membranes and upper respiratory tract.

E.3.2.3 Systemic Effects

No systemic toxicity results from DCDMH exposure.

E.3.2.4 Mutagenesis and Carcinogenesis

Data indicate that DCDMH is not mutagenic and suggest that this chemical is not a human carcinogen.

E.3.2.5 Reproductive and Developmental Toxicity

Limited data suggest that DCDMH is not a human reproductive or developmental toxicant.

E.3.2.6 Exposure-Response Data and Standards

TLV	0.2 mg/m^3 TWA	OSHA
	0.4 mg/ m^3 ceiling	OSHA
PEL	0.2 mg/m^3 TWA	OSHA
IDLH	5 mg/m^3	NIOSH, 1998

E.3.2.7 References

National Institute for Occupational Safety and Health. 1998. NIOSH Chemical Listing and Documentation of Revised IDLH Values (as of 3/1/95). Available on the Internet at www.cdc.gov/niosh/idlh/idlhview.html.

National Library of Medicine. 1998. Chemical Carcinogenesis Information System, Toxicology Data Network. Available on the Internet at www.toxnet.nlm.nih.gov/sevlets/simple-search.

National Library of Medicine. 1998. Hazardous Substances Database, Toxicology Data Network. Available on the Internet at www.toxnet.nlm.nih.gov/servlets/simple-search.

Occupational Health and Safety Administration. Chemical Sampling Information database. Available on the Internet at www.osha-slc.gov/OCIS/toc_chemsamp.html.

E.3.3 Sodium Hydroxide (NaOH)

Sodium hydroxide is toxic following inhalation, ingestion, and dermal and ocular exposure.

E.3.3.1 Eye and Skin Toxicity

Concentrated sodium hydroxide is an extremely corrosive base that may cause severe irritation of and burns to the eyes and skin. Prolonged or repeated exposures may result in conjunctivitis or dermatitis.

E.3.3.2 Inhalation Effects

Inhalation of sodium hydroxide dusts or mists may be extremely irritating to the upper respiratory tract and lungs. In addition, inhalation of high concentrations of sodium hydroxide may result in pulmonary inflammation.

E.3.3.3 Systemic Effects

Ingestion of sodium hydroxide may be fatal. Symptoms of sodium hydroxide ingestion include severe burns to the mouth, throat, and stomach, nausea, vomiting, and difficulty swallowing due to swelling of the esophagus.

E.3.3.4 Mutagenesis and Carcinogenesis

Data indicate that sodium hydroxide is not a human carcinogen.

E.3.3.5 Reproductive and Developmental Toxicity

Data indicate that sodium hydroxide is not a human reproductive or developmental toxicant.

E.3.3.6 Exposure-Response Data and Standards

TLV	2 mg/m^3 ceiling	OSHA
PEL	2 mg/m^3 TWA	OSHA
ERPG-1	0.5 mg/m^3	AIHA, 1999
TEEL-1	2 mg/m^3	U.S. DOE, 1999
IDLH	10 mg/m^3	NIOSH, 1998

E.3.3.7 References

American Industrial Hygiene Association. 1999. Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook. Fairfax, VA.

Cornell University. 1998. Material Safety Data Sheets database. Available on the Internet at www.MSDS.PDC.CORNELL.EDU/.

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National Institute for Occupational Safety and Health. 1998. NIOSH Chemical Listing and Documentation of Revised IDLH Values (as of 3/1/95). Available on the Internet at www.cdc.gov/niosh/idlh/idlhview.html.

National Library of Medicine. 1998. Hazardous Substances Database, Toxicology Data Network. Available on the Internet at www.toxnet.nlm.nih.gov/servlets/simple-search.

Occupational Health and Safety Administration. Chemical Sampling Information database. Available on the Internet at www.osha-scl.gov/OCIS/toc_chemsamp.html.

U.S. Department of Energy, Subcommittee on Consequence Assessment and Protective Actions. 1999. ERPGs and Recommended TEELs. Available on the Internet at tis.eh.doe.gov/web/chem_safety/teelintro.html.

E.3.4 Sodium Hypochlorite (NaOCl)

Exposure to sodium hypochlorite can occur by inhalation, ingestion, and dermal and ocular contact.

E.3.4.1 Eye and Skin Toxicity

Contact with concentrated sodium hypochlorite may be irritating to the eyes and skin. Contact with the eyes may result in conjunctivitis. Prolonged or repeated dermal exposures may cause dermatitis.

E.3.4.2 Inhalation Effects

Sodium hypochlorite vapors or mists may be highly irritating to the respiratory tract and may result in coughing, choking, difficulty breathing, and possible pulmonary edema.

E.3.4.3 Systemic Effects

Ingestion of sodium hypochlorite causes pain, inflammation, and tissue damage to the mouth, and upper gastrointestinal tract. Nausea and vomiting are common. Other systemic effects following sodium hypochlorite ingestion include confusion, delirium, coma, and convulsions. Following high oral exposures, severe shock and death may occur.

E.3.4.4 Mutagenesis and Carcinogenesis

Data suggest that sodium hypochlorite is not a human carcinogen.

E.3.4.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.3.4.6 Exposure-Response Data and Standards

TEEL-1	75 mg/m^3	U.S. DOE, 1999

E.3.4.7 References

Cornell University. 1998. Material Safety Data Sheets database. Available on the Internet at www.MSDS.PDC.CORNELL.EDU/.

Fisher Chemical Company. Catalog and Material Safety Data Sheets. Available on the Internet at www.fisher1.com.

National Library of Medicine. 1998. Chemical Carcinogenesis Information System, Toxicology Data Network. Available on the Internet at www.toxnet.nlm.nih.gov/servlets/simple-search.

National Library of Medicine. 1998. Hazardous Substances Database, Toxicology Data Network. Available on the Internet at www.toxnet.nlm.nih.gov/servlets/simple-search.

U.S. Department of the Army. 1996. Health and Safety Plan for Rapid Response System Operation at Deseret Chemical Depot, Utah. Aberdeen Proving Ground, MD.

U.S. Department of Energy, Subcommittee on Consequence Assessment and Protective Actions. 1999. ERPGs and Recommended TEELs. Available on the Internet at tis.eh.doe.gov/web/chem_safety/teelintro.html.

E.3.5 t-Butyl Alcohol

Exposure to t-butyl alcohol can occur by inhalation, ingestion, and dermal and ocular contact.

E.3.5.1 Eye and Skin Toxicity

Exposure to t-butyl alcohol may be irritating to the eyes or skin. In addition, significant amounts of t-butyl alcohol can be absorbed through the skin.

E.3.5.2 Inhalation Effects

t-Butyl alcohol is irritating to the mucous membranes and upper respiratory tract. Symptoms of inhalation exposure include coughing, difficulty breathing, and pulmonary edema.

E.3.5.3 Systemic Effects

Ingestion of t-butyl alcohol may cause nausea, vomiting, and diarrhea. Systemic effects result from depression of the central nervous system and include headache, muscle weakness, incoordination, confusion, delirium, and possible coma. t-Butyl alcohol exposure may also cause gastrointestinal bleeding, kidney damage, liver damage, and respiratory and cardiac failure.

E.3.5.4 Mutagenesis and Carcinogenesis

Data suggest that t-butyl alcohol is not a human carcinogen.

E.3.5.5 Reproductive and Developmental Toxicity

Data indicate that t-butyl alcohol is not likely to be a human reproductive or developmental toxicant.

E.3.5.6 Exposure-Response Data and Standards

LD_{50}	100-200 mL (oral; estimated)	Hazardous Substances Database, 1998
TLV	100 ppm (303 mg/m^3) TWA	U.S. Army, 1996
	150 ppm STEL	U.S. Army, 1996
PEL	100 ppm (300 mg/m^3) TWA	OSHA
TEEL-1	150 ppm	U.S. DOE, 1999
IDLH	1600 ppm	NIOSH, 1998

E.3.5.7 References

National Institute for Occupational Safety and Health. 1998. NIOSH Chemical Listing and Documentation of Revised IDLH Values (as of 3/1/95). Available on the Internet at www.cdc.gov/niosh/idlh/idlhview.html.

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U.S. Department of the Army. 1996. Health and Safety Plan for Rapid Response System Operation at Deseret Chemical Depot, Utah. Aberdeen Proving Ground, MD.

U.S. Department of Energy, Subcommittee on Consequence Assessment and Protective Actions. 1999. ERPGs and Recommended TEELs. Available on the Internet at tis.eh.doe.gov/web/chem_safety/teelintro.html.

E.4 Breakdown Products of Chemical Warfare Agents

Breakdown products are those chemicals that result from the degradation of the chemical warfare agents. The breakdown products described in this section of Appendix E are those of primary concern due to their relative environmental persistence and potential toxicity.

E.4.1 Arsenic (Inorganic)

Inorganic arsenic is a breakdown product of lewisite. Exposure to inorganic arsenic can occur by inhalation, ingestion, and dermal contact. Inorganic arsenic is ubiquitous in nature and can be found in the environment at concentrations which exceed those considered to be protective of human health. Toxicity varies with the chemical form of inorganic arsenic.

E.4.1.1 Eye and Skin Toxicity

Arsenical dusts are irritating to the eyes and may cause conjuntivitis, itching, and watering of the eyes. Exposure to inorganic arsenic is associated with hyperpigmentation of the skin and keratosis, especially of the palms of the hands and soles of the feet. Repeated exposures may result in dermatitis.

E.4.1.2 Inhalation Effects

Inhalation of arsenical dusts is irritating to the upper respiratory tract; destruction of the nasal tissues may occur.

E.4.1.3 Systemic Effects

Ingestion of inorganic arsenic may cause gastrointestinal inflammation and nausea. Possible systemic effects associated with exposure include functional disturbances of the peripheral nervous system, cardiac abnormalities, and coma.

E.4.1.4 Mutagenesis and Carcinogenesis

Although inorganic arsenic has been shown not to be mutagenic in a number of studies, exposure to this chemical is associated with an increased incidence of lung cancers, skin cancers, and cancers of the visceral organs (liver, bladder, kidney) in humans. Furthermore, inorganic arsenic has been classified as a known human carcinogen by the International Agency for Research on Cancer.

E.4.1.5 Reproductive and Developmental Toxicity

No adequate data are available to assess the human reproductive or developmental toxicity of this chemical. Inorganic arsenic is not teratogenic in animals when administered orally or via inhalation, although malformations do occur when this chemical is injected at high doses into animals. In addition, exposure to inorganic arsenic at maternally toxic doses is associated with decreased fetal weights and increased fetal deaths in animals.

E.4.1.6 Exposure-Response Data and Standards

TLV	0.01 mg/m^3 TWA	OSHA
PEL	0.01 mg/m^3 TWA	OSHA
RfD	0.3 μg/kg/day	U.S. EPA, 1998
RfC	0.0179 $\mu g/m^3$	U.S. Army CHPPM, 1999b
Cancer SF	1.5 $(mg/kg/day)^{-1}$	U.S. EPA, 1998
Cancer unit risk	0.00005 $(\mu g/L)^{-1}$	U.S. EPA, 1998

TEEL-1	0.03 mg/m^3	U.S. DOE, 1999
IDLH	5 mg/m^3	NIOSH, 1998

E.4.1.7 References

DeSesso, J.M., C.F. Jacobson, A.R. Scialli, C.H. Farr, and J.F. Holson. 1998. An assessment of the developmental toxicity of inorganic arsenic. Reproductive Toxicology 12:385-433.

Leonard, A. and R.R. Lauwerys. 1980. Carcinogenicity, teratogenicity and mutagenicity of arsenic. Mutation Research 75:49-62.

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U.S. Army Center for Health Promotion and Preventive Medicine. 1999a. Derivation of Health-Based Environmental Screening Levels for Chemical Warfare Agents, A Technical Evaluation. Aberdeen Proving Ground, MD. Prepared in conjunction with the Oak Ridge National Laboratory, Oak Ridge, TN.

U.S. Army Center for Health Promotion and Preventive Medicine. 1999b. Preliminary Assessment of Health impacts for the Newport Chemical Agent Disposal Facility, Newport, Indiana. Aberdeen Proving Ground, MD.

U.S. Environmental Protection Agency. 1998. Integrated Risk Information System database. Available on the Internet at www.epa.gov/iris/.

E.4.2 2-Chlorovinyl Arsenous Acid

2-Chlorovinyl arsenous acid is a hydrolysis breakdown product of lewisite. Limited toxicity data are available for this chemical.

E.4.2.1 Eye and Skin Toxicity

Because limited toxicity data are available for this chemical, it should be considered as toxic as its parent compound, lewisite.

E.4.2.2 Inhalation Effects

Because limited toxicity data are available for this chemical, it should be considered as toxic as its parent compound, lewisite.

E.4.2.3 Systemic Effects

Because limited toxicity data are available for this chemical, it should be considered as toxic as its parent compound, lewisite.

E.4.2.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of this chemical.

E.4.2.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.4.2.6 Exposure-Response Data and Standards

RfD	0.1 µg/kg/day	U.S. Army CHPPM, 1999

E.4.2.7 References

Munro, N.B., S.S. Talmage, G.D. Griffin, L.C. Waters, A.P. Watson, J.F. King, and V. Hauschild. In press. The sources, fate, and toxicity of chemical warfare agent degradation products. Environmental Health Perspectives.

U.S. Army Center for Health Promotion and Preventive Medicine. 1999. Derivation of Health-Based Environmental Screening Levels for Chemical Warfare Agents, A Technical Evaluation. Aberdeen Proving Ground, MD. Prepared in conjunction with the Oak Ridge National Laboratory, Oak Ridge, TN.

E.4.3 *S*-(Diisopropylaminoethyl) Methylphosphonothiolate (EA-2192)

EA-2192 is a hydrolysis breakdown product of agent VX. Limited toxicity data are available for this chemical.

E.4.3.1 Eye and Skin Toxicity

EA-2192 is not likely to be absorbed dermally to any significant extent.

E.4.3.2 Inhalation Effects

Due to the low volatility of EA-2192, it is not likely to be an inhalation hazard.

E.4.3.3 Systemic Effects

EA2192 is known to retain some of the anticholinesterase activity of its parent compound, VX. Because limited toxicity data are available for this chemical, it should be considered as toxic as VX.

E.4.3.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of this chemical.

E.4.3.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.4.3.6 Exposure-Response Data and Standards

RfD	0.0006 μg/kg/day	U.S. Army CHPPM, 1999a
RfC	0.0007 $\mu g/m^3$	U.S. Army CHPPM, 1999b

E.4.3.7 References

Munro, N.B., S.S. Talmage, G.D. Griffin, L.C. Waters, A.P. Watson, J.F. King, and V. Hauschild. In press. The sources, fate, and toxicity of chemical warfare agent degradation products. Environmental Health Perspectives.

Program Manager for Chemical Demilitarization. 1988. Chemical Stockpile Disposal Program Final Programmatic Environmental Impact Statement, Volume 3, Appendices A-S. Aberdeen Proving Ground, MD.

U.S. Army Center for Health Promotion and Preventive Medicine. 1999a. Derivation of Health-Based Environmental Screening Levels for Chemical Warfare Agents, A Technical Evaluation. Aberdeen Proving Ground, MD. Prepared in conjunction with the Oak Ridge National Laboratory, Oak Ridge, TN.

U.S. Army Center for Health Promotion and Preventive Medicine. 1999b. Preliminary Assessment of Health impacts for the Newport Chemical Agent Disposal Facility, Newport, Indiana. Aberdeen Proving Ground, MD.

E.4.4 Ethyl Methylphosphonic Acid

Ethyl methylphosphonic acid is a breakdown product of VX. Limited toxicity data are available for this chemical. Ethyl methylphosphonic acid is considered to have low to moderate toxicity.

E.4.4.1 Eye and Skin Toxicity

No data are available to assess the ocular and dermal toxicity associated with exposure to this chemical.

E.4.4.2 Inhalation Effects

No data are available to assess the effects associated with inhalation of ethyl methylphosphonic acid.

E.4.4.3 Systemic Effects

No data are available to assess the systemic effects associated with exposure to this chemical.

E.4.4.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of this chemical.

E.4.4.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.4.4.6 Exposure-Response Data and Standards

RfD	28 μg/kg/day	U.S. Army CHPPM, 1999a
RfC	3.40 $\mu g/m^3$	U.S. Army CHPPM, 1999b

E.4.4.7 References

Munro, N.B., S.S. Talmage, G.D. Griffin, L.C. Waters, A.P. Watson, J.F. King, and V. Hauschild. In press. The sources, fate, and toxicity of chemical warfare agent degradation products. Environmental Health Perspectives.

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U.S. Army Center for Health Promotion and Preventive Medicine. 1999a. Derivation of Health-Based Environmental Screening Levels for Chemical Warfare Agents, A Technical Evaluation. Aberdeen Proving Ground, MD. Prepared in conjunction with the Oak Ridge National Laboratory, Oak Ridge, TN.

U.S. Army Center for Health Promotion and Preventive Medicine. 1999b. Preliminary Assessment of Health impacts for the Newport Chemical Agent Disposal Facility, Newport, Indiana. Aberdeen Proving Ground, MD.

E.4.5 Isopropyl Methylphosphonic Acid

Isopropyl methylphosphonic acid is a hydrolysis breakdown product of sarin. This chemical is considered to have low toxicity.

E.4.5.1 Eye and Skin Toxicity

No data are available to assess the ocular and dermal toxicity associated with exposure to this chemical.

E.4.5.2 Inhalation Effects

No data are available to assess the effects associated with inhalation of isopropyl methylphosphonic acid.

E.4.5.3 Systemic Effects

No data are available to assess the systemic effects associated with exposure to this chemical.

E.4.5.4 Mutagenesis and Carcinogenesis

In a limited number of studies, isopropyl methylphosphonic acid has been shown not to be mutagenic. However, no data are available to assess the carcinogenic potential of this chemical in humans.

E.4.5.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical. However, diisopropyl methylphosphonic acid, which is known to be rapidly metabolized to isopropyl methylphosphonic acid, has been shown not to be developmentally toxic in laboratory animals.

E.4.5.6 Exposure-Response Data and Standards

RfD	100 μg/kg/day	U.S. Army CHPPM, 1999

E.4.5.7 References

Munro, N.B., S.S. Talmage, G.D. Griffin, L.C. Waters, A.P. Watson, J.F. King, and V. Hauschild. In press. The sources, fate, and toxicity of chemical warfare agent degradation products. Environmental Health Perspectives.

Program Manager for Chemical Demilitarization. 1988. Chemical Stockpile Disposal Program Final Programmatic Environmental Impact Statement, Volume 3, Appendices A-S. Aberdeen Proving Ground, MD.

U.S. Army Center for Health Promotion and Preventive Medicine. 1999. Derivation of Health-Based Environmental Screening Levels for Chemical Warfare Agents, A Technical Evaluation. Aberdeen Proving Ground, MD. Prepared in conjunction with the Oak Ridge National Laboratory, Oak Ridge, TN.

U.S. Environmental Protection Agency. 1998. Integrated Risk Information System database. Available on the Internet at www.epa.gov/iris/.

E.4.6 Lewisite Oxide

Lewisite oxide, also known as 2-chlorovinyl arsenous oxide, is a breakdown product of lewisite.

E.4.6.1 Eye and Skin Toxicity

Lewisite oxide has similar vesicant activity to that of its parent compound, lewisite. Because limited toxicity data are available for this chemical, it should be considered as toxic as lewisite.

E.4.6.2 Inhalation Effects

Because limited toxicity data are available for this chemical, it should be considered as toxic as its parent compound, lewisite.

E.4.6.3 Systemic Effects

Because limited toxicity data are available for this chemical, it should be considered as toxic as its parent compound, lewisite.

E.4.6.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of this chemical.

E.4.6.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.4.6.6 Exposure-Response Data and Standards

RfD	0.1 µg/kg/day	U.S. Army CHPPM, 1999

E.4.6.7 References

Munro, N.B., S.S. Talmage, G.D. Griffin, L.C. Waters, A.P. Watson, J.F. King, and V. Hauschild. In press. The sources, fate, and toxicity of chemical warfare agent degradation products. Environmental Health Perspectives.

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E.4.7 Methyl Phosphonic Acid

Methyl phosphonic acid is a breakdown product of sarin, soman, and agent VX. Exposure to this chemical can occur by inhalation, ingestion, and dermal contact. Limited toxicity data are available for methyl phosphonic acid.

E.4.7.1 Eye and Skin Toxicity

Direct exposure to methyl phosphonic acid is extremely irritating to the eyes and skin and may cause burns.

E.4.7.2 Inhalation Effects

Methyl phosphonic acid is extremely destructive to the mucous membranes and upper respiratory tract. Inhalation of this chemical may result in inflammation of the respiratory tract, pneumonitis, and pulmonary edema.

E.4.7.3 Systemic Effects

Systemic effects associated with exposure to methyl phosphonic acid include a burning sensation, coughing, wheezing, shortness of breath, headache, nausea, and vomiting.

E.4.7.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of this chemical.

E.4.7.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.4.7.6 Exposure-Response Data and Standards

RfD	20 μg/kg/day	U.S. Army CHPPM, 1999a
RfC	3.40 $\mu g/m^3$	U.S. Army CHPPM, 1999b

E.4.7.7 References

Cornell University. 1998. Material Safety Data Sheets database. Available on the Internet at www.MSDS.PDC.CORNELL.EDU/.

Munro, N.B., S.S. Talmage, G.D. Griffin, L.C. Waters, A.P. Watson, J.F. King, and V. Hauschild. In press. The sources, fate, and toxicity of chemical warfare agent degradation products. Environmental Health Perspectives.

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E.4.8 Thiodiglycol

Thiodiglycol is a hydrolysis breakdown product of sulfur mustard. This chemical is considered to be relatively nontoxic.

E.4.8.1 Eye and Skin Toxicity

Thiodiglycol is a mild eye and skin irritant.

E.4.8.2 Inhalation Effects

This chemical is irritating to the mucous membranes.

E.4.8.3 Systemic Effects

No data are available to assess the human systemic effects associated with exposure to thiodiglycol.

E.4.8.4 Mutagenesis and Carcinogenesis

No data are available to assess the mutagenic or carcinogenic potential of this chemical.

E.4.8.5 Reproductive and Developmental Toxicity

No data are available to assess the human reproductive or developmental toxicity of this chemical.

E.4.8.6 Exposure-Response Data and Standards

RfD	170 µg/kg/day	U.S. Army CHPPM, 1999

E.4.8.7 References

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E.4.9 Vinyl Chloride

Vinyl chloride is a breakdown product of lewisite; it results from the degradation of the initial lewisite breakdown products 2-chlorovinyl arsenous acid and lewisite oxide.

E.4.9.1 Eye and Skin Toxicity

Vinyl chloride is irritating to both skin and eyes. Exposure to this chemical is associated with a skin condition called scleroderma, in which the skin becomes hardened and thickened.

E.4.9.2 Inhalation Effects

Inhalation of vinyl chloride is irritating to the respiratory tract.

E.4.9.3 Systemic Effects

At high doses, vinyl chloride depresses the central nervous system. Exposure to this chemical is associated with weakness, drowsiness, visual disturbances, dizziness, nausea, and headache. In addition, vinyl chloride exposure has been shown to cause functional disturbances of the nervous system.

E.4.9.4 Mutagenesis and Carcinogenesis

Vinyl chloride has been shown to be mutagenic and to cause chromosomal aberrations. Human exposure to this chemical is associated with cancers of the nervous system, lungs, and liver. In addition, vinyl chloride has been classified as a known human carcinogen by the International Agency for Research on Cancer.

E.4.9.5 Reproductive and Developmental Toxicity

No adequate data are available to assess the human reproductive or developmental toxicity of this chemical. However, animal data suggest that vinyl chloride exposure at high concentrations may be associated with increased embryonic and fetal deaths, with decreased fetal weights, and possibly with malformations. In addition, vinyl chloride exposure in animals has been shown to adversely affect reproductive ability.

E.4.9.6 Exposure-Response Data and Standards

TLV	5 ppm (13 mg/m^3) TWA	OSHA
PEL	1 ppm (2.6 mg/m^3) TWA	OSHA
	5 ppm (13 mg/m^3) ceiling	OSHA
Cancer SF	1.9 (mg/kg/day)$^{-1}$	U.S. EPA, 1997
Cancer unit risk	0.000054 (µg/L)$^{-1}$	U.S. EPA, 1997
TEEL-1	5 ppm (13 mg/m^3)	U.S. DOE, 1999

E.4.9.7 References

Munro, N.B., S.S. Talmage, G.D. Griffin, L.C. Waters, A.P. Watson, J.F. King, and V. Hauschild. In press. The sources, fate, and toxicity of chemical warfare agent degradation products. Environmental Health Perspectives.

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E.5 Glossary

Acetylcholine: A chemical messenger that, when released from nerve endings, transmits a signal across a synapse to other nerves, muscles, glands, or internal organs.

Acetylcholinesterase: The enzyme that degrades acetylcholine, thus preventing it from continuing to transmit a signal from one nerve to another nerve, muscle, gland or internal organ.

Acetylcholinesterase inhibitor: A chemical substance that binds to and inhibits the normal function of the enzyme acetylcholinesterase. Inhibition of acetylcholinesterase results in an accumulation of acetylcholine in synapses, which causes stimulation and, in some cases, subsequent depression of the central and peripheral nervous systems. Consequences of exposure to an acetylcholinesterase inhibitor include increased salivation and perspiration, nausea, vomiting, difficulty breathing, muscular weakness, tremors, paralysis, and possibly death due to respiratory failure.

Acute: Short-term, sometimes a single event.

Agent: Something that causes an effect in a living organism. This effect can be either beneficial or detrimental. Examples of agents include chemical substances (e.g., penicillin, arsenic), biological organisms (e.g., bacteria), and forms of energy (e.g., x-rays, radiant heat).

Airborne exposure limit (AEL): An exposure limit set, for example, by the U.S. Army. To ensure safety, air concentrations of a chemical should not exceed its AEL.

Alkylating agent: A chemical that can irreversibly add a carbon-hydrogen structure to a protein or DNA molecule, thereby altering its molecular structure and perhaps disrupting its function.

Anemia: A reduction in the number or volume of red blood cells, or in the quantity of hemoglobin (the protein that carries oxygen in the blood). This leads to a decreased supply of oxygen to the body's tissues.

Anticholinergic: Having the ability to block the action of acetylcholine at nerves, muscles, glands, or internal organs. Symptoms of exposure to anticholinergic agents include flushing of the skin, fever, dry mouth, and hallucinations.

Bile: A yellowish secretion of the liver that aids in the digestion of fats.

Bile ducts: The tubular structures through which bile flows from the liver to the small intestine.

Blistering agent: Vesicant; a chemical that causes the formation of blisters on the skin following dermal contact with its vapors or liquid form.

Bronchitis: Inflammation of the bronchi and their branches.

Bronchopneumonia: Inflammation of the lungs following an infection in the bronchi and their branches.

Bronchus (pl. bronchi): One of the large airways that further branches and leads into the lungs.

Cancer slope factor: Defined by the U.S. EPA to be a plausible upper-bound estimate of the probability of a 70-kg human developing cancer following the breathing of contaminated air (at 1 $\mu g/m^3$) or the drinking of 2 L per day of contaminated water (at 1ppm) over a 70-year life span.

Cancer unit risk: Defined by the U.S. EPA to be an estimate of the increased individual lifetime risk of cancer for a 70-kg human breathing contaminated air (at 1 $\mu g/m^3$) or drinking 2 L per day of contaminated water (at 1ppm) over a 70-year life span.

Carcinogen: An agent that is capable of producing cancer.

Carcinogenesis: The production of cancer.

Cardiovascular: Pertaining to the heart and blood vessels.

Ceiling limit: An air concentration that should not be exceeded at any time, for any duration.

Central nervous system: The brain and spinal cord.

Choking agent: A chemical that causes difficulty in breathing by irritating or constricting the airways.

Chronic: Persisting or occurring over a long period of time.

Conjunctivitis: Inflammation of the membranes that line the inner surface of the eyelids and that cover the exposed surface of the eyeball.

Cornea: The transparent covering over the front of the eyeball.

Cumulative: Building up over time or with repeated exposures.

Cyanosis: A bluish discoloration of the skin and mucous membranes due to decreased oxygenation of the blood.

Cytotoxic: Capable of killing or poisoning cells.

Defecation: The discharge of feces from the bowels.

Degradation: Breakdown, decomposition.

Dermal: Pertaining to the skin.

Dermatitis: Inflammation of the skin.

Detoxification: The process by which a chemical is made less toxic, usually achieved by metabolism or by degradation of the chemical.

Developmental toxicity: Adverse effects on the unborn offspring as a result of exposure of the pregnant female to an agent. Manifestations may include (1) the death of the embryo or fetus, (2) structural malformations, (3) decreased size or weight of the offspring, and/or (4) functional (especially mental) deficits.

DNA (deoxyribonucleic acid): A large molecule, composed of subunits, that contains the hereditary information necessary for the development and functioning of a living organism. A *gene* is a portion of a DNA molecule that gives a particular instruction.

Dose: The amount of an agent (especially a chemical) to which a person or an animal is exposed.

Edema: the presence of an excessive amount of fluid between cells and in cavities of the body.

Embryo: The unborn offspring during the early stages of development; in humans, the embryonic period is from one week after conception to the end of the second month of pregnancy.

Emergency response planning guideline–1 (ERPG-1): An exposure limit set by AIHA to assist in emergency response personnel planning. The maximum airborne concentration of a chemical below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.

Erythema: Redness of the skin.

Exposure-response: The relationship between the quantity of an agent to which an individual is exposed and the resulting intensity of the toxic or therapeutic action.

Fetus: The unborn offspring during the later stages of development; in humans, the fetal period is from the third month of pregnancy to birth.

Gall bladder: A muscular organ under the liver in which bile, secreted by the liver, is concentrated and stored until its release into the small intestine.

Gastrointestinal tract: The stomach and intestines.

Hallucination: A false sensation (sight, sound, taste, smell, or touch) that has no basis in reality.

Hemolytic anemia: Anemia characterized by the destruction of red blood cells and the release of the oxygen-carrying protein hemoglobin from these cells.

Hydrolysis: The decomposition of a chemical by its reaction with water.

Hyperpigmentation: Abnormal darkening of areas of the skin.

Hypersensitive: Having an abnormally increased or exaggerated response to an agent.

Immediately dangerous to life and health (IDHL): Defined by NIOSH to be an air concentration of a chemical that is likely to cause (1) death, (2) immediate or delayed permanent adverse health effects, or (3) the inability to escape from the exposure.

Incapacitate: To deprive an individual of strength or the ability to function.

Ingestion: The process of eating.

Inhalation: The process of breathing in.

Iris: The circular, colored (e.g., brown, blue) portion of the eye.

Jaundice: A condition signaling dysfunction of the liver and characterized by a yellowish discoloration of the skin due to the increased presence of bile pigments in the blood.

Keratosis: The formation of horny growths of the skin, such as warts.

Lacrimation: The secretion of tears from glands above the eyeball.

Lacrimator: An agent that induces the secretion of tears from glands above the eyeball.

Malaise: A vague feeling of illness or discomfort.

Median incapacitating concentration (IC_{50}): The concentration of a chemical in air that will incapacitate 50 percent of an exposed population.

Median lethal concentration (LC_{50}): The concentration of a chemical in air or water that is lethal to 50 percent of an exposed population.

Median lethal dose (LD_{50}): The dose of a chemical that is lethal to 50 percent of an exposed population.

Metabolism: The chemical reactions that occur in the body, including the synthesis of large molecules like protein and DNA, and the breakdown of food and foreign chemicals.

Miosis: Excessive constriction of the pupil of the eye.

Mucous membrane: Mucosa; the thin lining of any internal surface of the body (e.g., the respiratory or digestive tract, including the nasal passages and the inside of the mouth).

Mustard gases: A family of volatile chemicals that cause the formation of blisters on exposed skin.

Mutagenesis: The production of mutations.

Mutation: A change in the structure of the DNA of a cell; this change can be passed on to the next generation of cells during cell division/proliferation.

Necrosis: The death of cells that make up a portion of a tissue or organ.

Nerve agent: A chemical that interferes with the normal functions of the central and/or peripheral nervous systems.

Neurotransmitter: Any chemical messenger that, when released from nerve endings, transmits a signal across a synapse to other nerves, muscles, glands, or internal organs.

Norepinephrine: A chemical messenger that, when released from nerve endings, transmits a signal to nerves of the central nervous system or to the muscles of the heart, blood vessels, and gastrointestinal tract.

Ocular: Pertaining to the eye.

Peripheral nervous system: All of the nerves outside of the brain and spinal cord.

Permissible exposure level (PEL): An exposure level limit set by OSHA. Workers should not be exposed to air concentrations higher than the PEL. The exposure level limits reported in this appendix are given as time-weighted averages (TWAs), short-term exposure limits (STELs), or ceiling limits.

Photophobia: Abnormal sensitivity to light.

Pneumonia: Acute or chronic inflammation of the lungs, characterized by the release of fluid and proteins from pulmonary blood vessels and the deposition of this material in the lungs.

Pneumonitis: Acute, localized inflammation of the lungs without the systemic effects seen with pneumonia.

Potency: Strength in inducing biological effects.

Pulmonary: Pertaining to the lungs.

Pupil: The black circle in the center of the iris of the eye; the window in the eye through which light enters.

Rales: Abnormal respiratory sounds (e.g., rasping, clicking, hissing).

Reference concentration (RfC): A daily inhalational exposure determined by the U.S. EPA to not cause adverse health effects in humans.

Reference dose (RfD): A daily oral exposure determined by the U.S. EPA to not cause adverse health effects in humans.

Reproductive toxicity: Damage to the male or female reproductive system. This damage may interfere with the production of viable eggs and sperm, their ability to fuse, and the ability of a female to maintain a pregnancy.

Respiratory tract: The nose, pharynx, larynx, trachea, bronchi, smaller airways, and lungs.

Sensitize: To expose an organism to a compound and, as a result, make the organism much more likely to experience adverse reactions to subsequent exposures to the compound.

Shock: A generally temporary state of massive physiological reaction to bodily trauma; symptoms include pale and clammy skin, decreased blood pressure, decreased respiration, and sometimes unconsciousness.

Short-term exposure limit (STEL): An air concentration averaged over (usually) 15 minutes that, to ensure safety, should not be exceeded.

Solubility: The degree to which a chemical disperses in another substance (e.g., water, lipid [fat], chloroform).

Stupor: Mental confusion; daze.

Synapse: The gap between a nerve and another nerve, muscle, gland, or internal organ. A chemical (e.g., acetylcholine, norepinephrine) must carry a nerve's signal across this gap.

Systemic effects: Refers to effects throughout the body as a result of an agent being absorbed into the body and present in the bloodstream. These effects are distinguished from *local* effects, which occur at the site of exposure (e.g., on the skin after dermal exposure).

Temporary emergency exposure limit-1 (TEEL-1): An exposure limit adopted by the U.S. DOE for chemicals for which ERPGs have not yet been developed. The maximum concentration in air below which it is believed that nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

Teratogenic: Capable of producing structural malformations in the offspring of an exposed pregnant female.

Threshold: The dose or concentration of a chemical below which no measurable or observable effect occurs.

Threshold limit value (TLV): An exposure limit set by ACGIH. The TLV is the concentration of a chemical to which it is believed that nearly all workers may be exposed day after day without adverse effect. The exposure limits reported in this appendix are given as time-weighted averages (TWAs), short-term exposure limits (STELs), or ceiling limits.

Time-weighted average (TWA): An air concentration averaged over an 8-hour workday and a 40-hour workweek that should not be exceeded.

Toxic: Poisonous; capable of disrupting the normal function of a cell, an organ, or an organism as a result of sufficient exposure.

Vapor: A chemical substance in the gaseous state at a temperature below the substance's boiling point.

Vertigo: Dizziness; the sensation that either the environment or oneself is whirling around.

Vesicant: Blistering agent; a chemical that causes the formation of blisters on the skin following dermal contact with its vapors or liquid form.

E.6 Acronyms, Abbreviations, and Units of Measure

μg	Microgram, a unit of mass equal to 1/1000 of a milligram or one-millionth of a gram
μg/kg/day	Microgram(s) per kilogram per day, a unit for daily doses or exposures
$\mu g/m^3$	Microgram(s) per cubic meter, a unit of concentration in air
AC	Hydrogen cyanide
ACGIH	American Conference of Governmental Industrial Hygienists
AEL	Airborne exposure limit
AIHA	American Industrial Hygiene Association
BBC	Bromobenzyl cyanide; also CA
BZ	3-Quinuclidinyl benzilate
CA	Bromobenzyl cyanide; also BBC
CG	Phosgene
CK	Cyanogen chloride
CN	Chloroacetophenone
CNB	Chloroacetophenone in benzene and carbon tetrachloride
CNS	Chloroacetophenone and chloropicrin in chloroform
DCDMH	1,3-Dichloro-5,5-dimethylhydantoin
DM	Adamsite
DNA	Deoxyribonucleic acid
DP	Diphosgene
ERPG-1	Emergency response planning guideline-1
GA	Tabun
GB	Sarin
GD	Soman
H	Sulfur mustard; also HS
HD	Distilled sulfur mustard
HL	A mixture of distilled sulfur mustard (HD) and lewisite (L)
HN-1	Nitrogen mustard 1
HN-2	Nitrogen mustard 2
HN-3	Nitrogen mustard 3
HS	Sulfur mustard; also H
HT	A mixture of distilled sulfur mustard (HD) and agent T (T)
IC_{50}	Mediating incapacitating concentration
IDLH	Immediately dangerous to life and health

kg	Kilogram, a unit of mass
L	Lewisite
LC_{50}	Median lethal concentration
LD_{50}	Median lethal dose
MEA	Monoethanolamine
mg	Milligram, a unit of mass equal to 1/1000 of a gram
mg/kg	Milligram(s) per kilogram of body weight, a unit used to normalize doses or exposures to body size
mg/kg/day	Milligram(s) per kilogram per day, a unit for daily doses or exposures
mg/m^3	Milligram(s) per cubic meter, a unit of concentration in air
$mg\text{-}min/m^3$	Milligram(s) a minute per cubic meter; the product of units of concentration and time: $mg/m^3 \times min$; the use of this unit lets one compare exposures of different durations based on the fact that a short exposure to a high concentration produces the same response as a long exposure to a low concentration
mL	Milliliter, a unit of volume equal to 1/1000 of a liter
NaOCl	Sodium hypochlorite
NaOH	Sodium hydroxide
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No observed adverse effect level
OSHA	Occupational Safety and Health Administration
PEIS	Programmatic Environmental Impact Statement
PEL	Permissible exposure level
ppm	Part(s) per million, a unit of concentration in water, air, or soil
PS	Chloropicrin
RfC	Reference concentration
RfD	Reference dose
SF	Slope factor
STEL	Short-term exposure limit
T	bis(2-(2-Chloroethylthio)-ethyl) ether
TEEL-1	Temporary emergency exposure limit-1
TLV	Threshold limit value
TWA	Time-weighted average
U.S. DOE	United States Department of Energy
U.S. EPA	United States Environmental Protection Agency
U.S. Army CHPPM	United States Army Center for Health Promotion and Preventive Medicine
VX	O-Ethyl-S-(2-diisopropylaminoethyl)-methyl phosphonothiolate
WP	White phosphorus

Appendix F

Environmental Fate of Non-Stockpile Chemicals and Neutralent Wastes

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Appendix F

Environmental Fate of Non-Stockpile Chemicals and Neutralent Wastes

This appendix summarizes relevant physical-chemical characteristics and environmental fate for those chemical warfare agents and industrial chemicals identified in Section 1.5, the treatment reagents used in the transportable treatment systems, and the neutralent wastes produced from treating chemical warfare agents and the industrial chemical phosgene. The information contained in the descriptions is primarily based on readily available technical literature that has been published by the Department of Defense and associated organizations. Particularly noteworthy is a review by scientists at Oakridge National Laboratory and the Aberdeen Proving Ground on the fate and toxicity of chemical warfare agents and degradation products [30]. As appropriate, additional information has been used to supplement this base of information. Details may be found in the references given at the end of this appendix. The subsequent fates of products of degradation of chemicals in the environments have also been discussed wherever scientific literature has been available. In some cases, conjectures as to the fate of chemicals have been made based upon the chemistry of closely related compounds.

It is important to note that the environmental fate of chemicals is discussed in this appendix as though no human intervention will take place after a release of chemicals has occurred. This is merely to point out how far nature will control these chemicals. However, when a chemical release into the environment takes place, the Army or other appropriate organizations will respond to the spill and remediate the environment by removal of the pollutants.

The discussion of each chemical consists of a series of descriptions presented in the following standardized format:

Summary—A summary description of the environmental fate of the chemical.

Chemical Identity—A description of the chemical, including synonyms for the chemical, type of chemical agent, molecular formula, and molecular weight.

Physical-Chemical Properties—A description of the physical and chemical properties of the chemical, including boiling point, freezing point, reactivity, rate of hydrolysis, hydrolysis products and oxidation products.

Environmental Fate and Transport—A discussion of the persistence of the chemical in different environmental media and the potential for bioaccumulation of the chemical.

Discussion is devoted to chemicals that may be released into the atmosphere, spilled onto soil, vegetation, or into water.

F.1 Overview of Environmental Processes

Most chemicals when released into the environment (soil, water, or atmosphere) undergo a variety of reactions or processes that affect their transport and fate. The following processes are relevant to the migration and fate of the identified chemicals of concern.

F.1.1 Transport of Chemicals

After chemicals are released into the environment they tend to migrate and at the same time may begin to degrade to other compounds. The movement or transport of chemicals in the environment is a function of the physical properties of both the chemicals and the matrix surrounding them. Volatility, solubility, and the degree to which chemicals associate with soil, sediment, and water are some of the physical properties that determine the extent of their transport. Climatic conditions also affect the movement of chemicals in the environment.

Hydrologic transport is a very significant process. Hydrologic transport refers to the movement of water and chemicals in the subsurface environment. Once in an aquatic system chemicals are subject to a number of chemical and biochemical processes, including acid-base, oxidation-reduction, precipitation-dissolution, hydrolysis, photolysis reactions, and also biodegradation. The chemical reactions are discussed below separately.

The surface soil is usually unsaturated (with water) and may depending upon climatic conditions may even be dry. Chemicals released into unsaturated soil may evaporate if the soil is dry. Liquids will percolate downward into the subsurface soil which is saturated with water. A primary control of transport of contaminants is the solubility of that contaminant. Substances having low water solubilities (hydrophobic constituents) such as chlorocarbon compounds move some distance downward from the source of contamination as non-aqueous phase liquids. As they move through the subsurface, residual amounts of the contaminants are left behind in the path traversed. These residual amounts may be sorbed onto soil particles (see below). Denser hydrophobic chemicals usually migrate vertically downward until a hydrologic barrier, such as an aquitard is reached and accumulate there. Hydrophobic compounds have a finite solubility in water, however small, and after these compounds settle at the aquitard very small amounts of these compounds will be transported as solutions in water and eventually dissipate. Hydrophobic compounds lighter than water (e.g., benzene or toluene) will tend to be transported as light non-aqueous phase liquids. If small amounts of these chemicals are spilled they will most likely evaporate off. If large quantities are involved, they will travel downward in the subsurface to the top of the soil saturated with water and float on the water table and move laterally in the direction of the slope of the water table

Compounds soluble in water move with groundwater and this movement tends to increase during rainfall or alongside rivers and streams. This tendency of water to hold the chemical is a factor in its mobility. For example, although methanol has a higher evaporation rate and lower boiling point than toluene, vapors of toluene are more readily evolved from soil and water because of its limited solubility in water as opposed to methanol, which is

fully miscible with water. Prior presence of organic compounds in water has a tendency to increase the solubility of waste organic chemicals.

Chemicals that are chemically reactive or unstable or which are biochemically active will not move as far as the more stable chemicals do.

F.1.2 Adsorption

The process in which chemicals become associated with solid phases is generally referred to as *sorption*. When sorption occurs at the surface of a medium such as soil particles it is called *adsorption*. When chemicals penetrate into the matrix of soil or other solids it is called *absorption*. The degree of adsorption depends upon the surface properties of solids or soil, particularly its surface area. The degree of adsorption is dependent upon organic matter (humus) in the soil, presence of metals ions, types of clays present, and the chemical properties of the pollutant chemical.

Sorption can dramatically affect the fate and impact of chemicals in nature. Polar compounds such as acids and bases have a tendency to strongly sorb to soils and dynamically partition between soil and water depending upon their solubility in water. However, non-polar compounds and hydrophobic compounds are generally not soluble in water and tend to enter organic matter in the soil (proteins, lignin, cellulose, and macromolecules from degradation of microorganisms) and be retained there.

Also, those water-insoluble organic compounds, lighter than water, if not sorbed will escape into air. Sorbed molecules are rather protected from sunlight and will not degrade photochemically as rapidly as dissolved or air-borne species. Molecular transfer into bacteria is a prerequisite for biodegradation to occur. Dissolved molecules will enter bacteria with greater ease than molecules bound inside the soil or humus and thus dissolved compounds will undergo biodegradation more rapidly. Acidic chemicals such as carboxylic acids, and phosphorous or arsenic based acids may form salts with metal ions present in the soil. Such salts will be mobile if they are soluble in water. If these salts are insoluble in water they will precipitate out and become trapped in soil and more so in clay.

Mathematically, the distribution of a chemical between groundwater and soil is expressed by a *distribution coefficient,* $\mathbf{K_d}$ that is the ratio of concentration of the chemical in soil (C_s) to the concentration of that chemical in groundwater (C_w).

$$\mathbf{K_d} = C_s/C_w$$

Hydrophobic compounds tend to have high values of K_d. When K_d is high, 2-10, such compounds are considered to have low mobility. Values of K_d less than 0.1 imply high mobility in groundwater.

Another mathematical quantity called the "octanol-water partition coefficient", $\mathbf{K_{ow}}$, is used as a measure of the tendency of a chemical to partition between groundwater and

organic matter in soil. K_{ow} is the ratio of the concentration of a chemical in octanol to its concentration in water.

$$\mathbf{K_{ow}} = C_o/C_w$$

If Log K_{ow} is greater than 3 for a given chemical then that chemical preferentially partitions into organic matter. This term is useful to determine if pollutant chemical enter organisms and plants in the environment and accumulate there. Less reactive and hydrophobic compounds such as PCB's halocarbons tend to bioaccumulate.

Summary of this discussion is sorption retards volatilization, bio-degradation, photodecomposition, and movement of chemicals in groundwater.

F.1.3 Volatilization

Volatilization is a process by which a chemical is transferred from soil or water into the atmosphere. Usually low boiling chemicals such as gasoline or chlorofluorocarbons evaporate with ease out of water and soil. Substances that are insoluble in water also volatilize into the atmosphere. Thus, such chemicals are not persistent in the environment. Chemicals that enter the atmosphere may also return to water and soil by condensation and sorption when the air temperature drops or they may be carried back to water and soil by rain. Chemicals that remain in the atmosphere will eventually degrade by direct photodecomposition in sunlight or by reaction with other radicals such as hydroxyl which are generated in sunlight.

The relationship between the concentration in air and in water is described by the Henry's Law constant, $\mathbf{K_H}$.

$$\mathbf{K_H} = [\text{Concentration in air}] / [\text{Concentration in water}]$$

The constant $\mathbf{K_H}$ is closely related to the vapor pressure of the chemical of concern. Generally, compounds prefer to remain in water if the vapor pressure is less than 10^{-7} mm/Hg or pose a K_H less than 5×10^{-6} atm.m^3/mole. Compounds tend to volatilize if the vapor pressure is greater than 10^{-2} mm/Hg or have K_H greater than 5×10^{-3} atm.m^3/mole· According to the USEPA, chemicals having a K_H greater than 1×10^{-5} atm-m^3/mol and a molecular weight of less than 200 are likely to volatilize from water or soil and represent an inhalation hazard.

It is important to note that volatilization is an important fate process for surface contamination in soil or water. In some groundwater systems, due to the depth of the water table, this is not a major process of dissipation.

F.1.4 Hydrolysis

Most chemicals dissolve in one solvent or another and form physical solutions without undergoing any chemical transformation. Dissolution of sugar in water is an example. On the other hand some chemicals undergo chemical transformation upon dissolution in a solvent.

This is called solvolysis. A specific instance of solvolysis is hydrolysis where the solvent is water. Water is abundant in nature and therefore hydrolysis of chemicals is a very important route of degradation of chemicals in the environment.

Hydrolysis is the reaction of chemicals with water or hydronium ions (H_3O^+) or hydroxide ions (OH^-). The typical reaction usually results in the introduction of a hydroxyl group (-OH) into the chemical molecule with the loss of a leaving group, such as a halide, an alkoxy group, or an organic sulfide group, etc. For example, ethylbromide hydrolyzes to ethanol.

$$CH_3CH_2\text{-}Br + OH^- \rightarrow CH_3CH_2\text{-}OH + Br^-$$

Factors such as pH of groundwater, and temperature, affect the rate of hydrolysis of chemicals. Higher temperatures tend to increase the rate of hydrolysis. As solubility increases the rate of hydrolysis also increases. Certain metal ions in water and soil catalyze hydrolysis of chemicals in groundwater and inside microorganisms. In certain instances if groundwater contains common anions, for example bromide in the above example, hydrolysis rates are decreased. A quantity typically reported with hydrolysis reactions is the half-life, $t_{1/2}$. The half-life of a compound in a given reaction is the time it takes to reduce the concentration of that compound by one half. Half-lives range from a few seconds to thousands of years. Molecules generally susceptible to hydrolysis are alkyl halides, chlorinated amides, esters, organic sulfides, organophosphates (e.g., pesticides, herbicides, and nerve agents). Examples of compounds not susceptible to hydrolysis are alkanes, alkenes, aldehydes, alcohols, amines, and carboxyl compounds.

F.1.5 Biodegradation

Removal or transformation of organic chemicals from the subsurface environment and from water can occur through the action of microorganisms in soil and water. Microorganisms are comprised of many forms including bacteria, protozoans, fungi, and microalgae and they are present virtually everywhere in nature even under extreme conditions of temperature, pressure, pH, salinity, oxygen, nutrients, and even low water content. Biodegradation of wastes is their conversion by biological processes to simple inorganic molecules, carbon dioxide, water, and to biological materials. The complete bioconversion of an organic compound to inorganic species such as carbon dioxide, ammonia, sulfate and phosphate is called *mineralization.* Mineralization does not occur in a single step. Several intermediate biological transformations must take place before mineralization becomes the result. In this context, *detoxification* refers to the biological conversion of a toxic compound to a less toxic compound.

Biodegradation occurs by metabolism of organic pollutants. Organisms consume nutrients in soil and water to obtain energy and build up life-molecules. This is *anabolism.* Breaking down the nutrient molecules as a source of carbon and energy is *catabolism.* Pollutant molecules are too low in concentration to be a significant source of carbon or energy but they are consumed by the organisms along with the nutrients. This is *cometabolism.* If nutrients are not present in the environment cometabolism of pollutants will not occur.

Biochemical transformations occur slowly. However, organisms enable metabolism to proceed at higher rates. They produce enzymes that are special proteins and serve as catalysts. Enzymes lower the amount of activation energy required to make and break chemical bonds thereby speeding up the reactions millions of times. Sorption of nutrients and pollutants to soil and humus slows down the degradation rate because sorption prevents the transfer of the chemicals to the interior of the organism. If this metabolism of nutrients and cometabolism of the pollutants results in energy yield or cell building materials, then the microorganism may increase in cell numbers. The additional microorganisms thus born will to increase degradation rates.

The most common type of biodegradation is that of organic compounds in the presence of air or oxygen. This is an *aerobic* process. Biodegradation in the absence of air is an *anaerobic* process. For example, hydrocarbons are much more persistent in the environment under anaerobic conditions for they require oxygen for oxidation to carbon dioxide and water. On the contrary, chlorinated compounds degrade rapidly under anaerobic conditions for they are reduced to hydrocarbons by removal of chlorine.

Once the enzymes and the pollutant have come together in the microorganism cells there are basically three types of reactions to initiate the breakdown of the pollutant molecules. These are, oxidation using atmospheric oxygen, reduction with hydrogen or electrons, and hydrolysis. These types of reactions have been discussed above. The only distinction here is that the enzymes mediate and catalyze these reactions.

Bio-reductions occur with compounds that generally contain carbonyl, nitro, sulfoxide, sulfone, and halogen groups. For example, aldehydes and ketones are reduced to alcohols by what are known as NADH and NADPH enzymes which mediate the transfer of hydrogen to the carbonyl group and convert it to a hydroxy group of the alcohol. Sulfoxides and sulfones are reduced to organic sulfides by removal of oxygen bound to the sulfur atoms. Halogen containing compounds successively lose the halogens as halide ions and convert to methane and other hydrocarbons under anaerobic conditions. For example, chloroform ($CHCl_3$) is reduced to methane and chloride by heme proteins.

Hydrolysis reactions that were discussed earlier also occur within the organisms. The pH of the cytoplasm in the organisms is not very different from that of natural waters and hydrolysis at such pH would be slow. Therefore, the organisms use enzymes that contain exceptionally good nucleophiles to initiate hydrolyses. Generally organic halogen compounds are hydrolyzed to alcohols, amides to amines, phosphates to derivatives of phosphoric acid, and thiophosphates to thiols. Once the more complex molecules such as aromatics or pesticides are broken down initially, mineralization will eventually be the fate.

This section will conclude with a few general remarks on the fate of different types of organic compounds of concern here due to microbal transformations. Hydrocarbons are generally cometabolized and oxidized to carbon dioxide as part of the carbon cycle. Methane

production is also generally observed. Nitrogen containing compounds such as amines, amides, and nitro compounds are converted to ammonia and ammonium ions (NH_4^+). Ammonium ions are *nitrified* by bacteria of the genus by *Nitrosomonas* and *Nitrobacter* to nitrate ions, which are absorbed by plants or returned to the atmosphere as nitrogen gas. Degradation of organic sulfur compounds by bacterially mediated processes results in the production of noxious and volatile alkyl thiols which are subsequently oxidized to alkyldisulfides. Hydrogen sulfide is also formed from a variety of organic sulfur compounds by microbal action. Organic phosphorus compounds such as insecticides and pesticides undergo mineralization that releases inorganic phosphate which is consumed by microbes as orthophosphate nutrient. Organic halogen compounds undergo reductive dehalogenation under anaerobic conditions, albeit slowly.

F.1.6 Oxidation and Reduction

Oxidation involves any one or all of the following changes in a molecule

- Loss of electrons
- Loss of hydrogen
- Gain of oxygen

Typical oxidation reactions include treatment processes using chlorine, sodium hypochlorite (bleach), chloramines such as dichlorodimethylhydantoin, or hydrogen peroxide. The result of a complete oxidation of an organic compound is its conversion to carbon dioxide and water as exemplified by burning of gasoline. Such powerful oxidation does not occur in subsurface systems. This occurs in nature under aerobic biodegradation conditions in water and at the surface. Example of an oxidation is the conversion of an organic sulfide to its sulfoxide.

$$C_2H_5\text{-}S\text{-}C_2H_5 + [O] \rightarrow (C_2H_5)_2SO$$

Most organic compounds do not react spontaneously at significant rates with molecular oxygen, which at pH of 7 is only a weak oxidant. Only compounds, which are very easily oxidized, will react with molecular oxygen in groundwater and air. Such compounds are organic sulfur compounds, aryl amines, and trivalent arsenicals. Overall, oxidation of organic compounds in subsurface groundwater systems is limited unless oxidizing agents (e.g., peroxides or nitrates) are added. Typically, such additions are used not to destroy the organic compounds directly but to create an aerobic condition to increase biological activity.

Chemicals may also undergo reduction reactions. Most organic compounds preferentially undergo reduction in the environment. Reduction involves any or all of the following transformations.

- Gain of electrons
- Gain of hydrogen
- Loss of oxygen

For example, in the presence of certain transition metal ions, such as iron porphyrins, reduction of chlorocarbon compounds can occur in groundwater. Initially electrons are transferred from a metal complex to the organic molecule. The result is loss of chloride ions and formation of alkyl radicals and then alkenes. The following reactions exemplify reductions that may occur in groundwater.

$$Cl_3C\text{-}CCl_3 + 2\ e^- \rightarrow Cl_2C{=}CCl_2 + 2\ Cl^-$$

$$C_6H_5\text{-}NO_2 + 6\ H^+ + 6\ e^-\text{-} \rightarrow C_6H_5\text{-}NH_2 + 2\ H_2O$$

F.1.7 Photolysis

Molecules may absorb light and as a consequence undergo chemical transformations. This process is called *direct photolysis.* Molecules absorb only radiation of specific wavelengths. Colorless compounds such as hydrocarbons and chlorocarbons absorb in the UV region of the spectrum. The intensity of UV radiation near the surface is quite low and therefore photolysis of such compounds is not an important process at the surface. However, volatile compounds such as chlorocarbons volatilize and are transported to the troposphere where they undergo photo-dissociation by absorption of more intense of short wavelength UV radiation.

The process of degradation of molecules by reaction with other species that are produced by direct photolysis is known as indirect photolysis. The hydroxyl radical $OH^{\cdot}$ is the single most reactive intermediate species in the atmosphere. At higher altitudes water absorbs UV radiation and dissociates to give hydroxyl and hydrogen radicals.

$$H_2O + \text{UV light} \rightarrow HO^{\cdot} + H^{\cdot}$$

The hydroxyl radical reacts rapidly with organic compounds in the atmosphere thereby causing indirect photodegradation of organic compounds. This type of reaction may be important in the upper atmosphere to where volatile compounds may rise.

Indirect photolysis can also be a significant process in surface waters. Nitrate ions are common in the subsurface environment and they absorb UV radiation and react with water to generate hydroxyl radicals. These hydroxyl radicals in turn degrade pollutant molecules in surface waters.

F.2 Chemical Warfare Agents

Chemical warfare agents are toxic compounds that were developed and manufactured specifically to be used by the military to kill, seriously injure, or incapacitate enemy soldiers through their physiological effects. These agents have very few, if any, other uses.

F.2.1 Sulfur Mustards (H, HD, HS, HT)

Synonyms: mustard gas; bis(2-chloroethyl)sulfide; 2, 2'-dichlorodiethyl sulfide

F.2.1.1 Summary

Sulfur mustards are a class of vesicant chemical agents comprised of sulfur mustard (H or HS), distilled mustard (HD), and mustard-T mixture (HT). HD is the purest form of sulfur mustard. HT is a mixture of distilled sulfur mustard and agent T (a mustard derivative similar to distilled sulfur mustard). At low concentrations in the environment, distilled sulfur mustard and related products are expected to quickly decompose in water but large releases may persist in soils for years after release.

F.2.1.2 Chemical Identity

Sulfur mustard is one of several types of organosulfur mustard compounds classified as blistering agents (vesicants). There are several designations for forms of this chemical agent. Distilled sulfur mustard is the most pure form, sometimes referred to as distilled or purified mustard. The active toxic chemical in these agents is identical, but the degree of impurities present in them varies. In the Levinstein process for preparing sulfur mustard, 30 percent of the mass of the total product may consist of inactive sulfide impurities. Distilled sulfur mustard is the most toxicologically potent of these agents. Mustard-T mixture is a mixture of 60 percent distilled sulfur mustard and 40 percent of bis(2-(2-chloroethylthio)ethyl) ether (T).

Tables F.2.1-1 and F.2.1-2 present the relevant chemical identity information for the sulfur mustards and mustard-T mixture. In these tables, and in the remaining text, most of the information presented relates to the pure distilled sulfur mustard form.

F.2.1.3 Physical-Chemical Properties

Tables F.2.1-3 and F.2.1-4 present a summary of physical and chemical properties of sulfur mustards. It is expected that the less potent form of sulfur mustard (H) will have the same physical, chemical, and toxic properties.

F.2.1.4 Environmental Fate and Transport

Atmospheric Fate

Release of sulfur mustard agents into the atmosphere results in droplet formation, with slow settling to land and water surfaces. HD has sufficient vapor pressure to volatilize from soils and enter the atmosphere. Norwegian field laboratory studies [2] have shown that more than 99% of mustards evaporated from vegetation, sand and soil in less than a day and was undetectable after 14 days. Evaporated HD can also deposit back to earth but its deposition back to earth is lower than sarin (see section F.2.4) and depends on the nature of the soil [1]. HT is less volatile and therefore less likely to volatilize. HD does not absorb visible or near UV radiation significantly and direct photodegradation in air is not a significant fate [34]. HD reacts with photochemically generated hydroxyl radicals in air and degrades rapidly. The sulfur from these molecules will end up as sulfur dioxide [44]. It has been shown that HD has a half-life of 1.4 days in air [29, 35]. No data is available on the fate of HT in air. However, because of its structural similarity to HD one can expect similar secondary photodegradation.

Aquatic Fate

Sulfur mustards have very low solubility in water. Sulfur mustard can be quickly hydrolyzed in rivers, lakes, and streams. Hydrolysis occurs rapidly (about 4 to 18 minutes) at 25°C, but at lower temperatures hydrolysis will occur very slowly because sulfur mustard forms liquid globules or crystals and dissolves very slowly. Upon initial entry to surface waters, small amounts of sulfur mustard may evaporate, but because sulfur mustards are denser than water, they rapidly form globules and sink to the bottom. It has been estimated that a 1-centimeter diameter droplet of sulfur mustard agent in fresh water has a half-life of approximately 5 weeks.

This discussion will focus on HD because this compound has been studied in great detail (see references to original papers in reference 20).

HD is very insoluble in water. HT is virtually insoluble in water. Thus, mustards, being denser than water, sink, persist undispersed in water, and will not travel with groundwater [41]. Volatilization from turbid waters can be significant.

Concentration of a saturated solution of HD in water at 37°C is only 634 mg/L [20]. Hydrolysis is the primary degradation route in water. The rate of hydrolysis is limited by the rate of dissolution of HD in water [36]. Hydrolysis of HD occurs at the HD/water interface [4,37,38]. The initial product is hemi-mustard ($Cl\text{-}CH_2CH_2\text{-}S\text{-}CH_2CH_2\text{-}OH$). The final products of a complex reaction in excess water are thiodiglycol (TDG) and hydrochloric acid. If insufficient water is present several stable complex compounds are initially formed. This retards the hydrolysis of more HD. These compounds eventually breakdown to TDG and HCl [37]. The generation of HCl lowers the pH of the aqueous medium. However, natural waters are buffered preventing drastic reduction in pH and the rate of hydrolysis is pH independent [4,36]. Half-life of HD in distilled water at 25°C is 14 to 16 minutes [31,40]. As the temperature rises the half-life decreases [31, 40]. These numbers are easy to misinterpret. This merely tells that once HD is dissolved in water it degrades very rapidly. However, as noted above HD has a very low solubility in water and does persist.

Under certain conditions minor quantities of 1,4-dithiane and 1,4-oxathiane are also formed in the hydrolysis of HD [73].

There is considerable literature on the fate of HD in seawater [42]. This will not be discussed here, as it is not relevant to the NSCM program. A noteworthy point from these studies is that presence of high concentration of chloride ions in water inhibits the hydrolysis of HD [43].

There is no literature on the direct photodegradation of mustard in water. Laboratory studies on dibutylsulfide (a HD simulant) show that it is resistant to irradiation in the absence of sensitizers [45]. One may conclude that HD would behave similarly.

HD, like other organic sulfides is susceptible to oxidation. If oxidants such as chlorine or hydrogen peroxide are present water HD is oxidized to the sulfoxide, $(ClCH_2CH_2)_2S{=}O$ and then to the sulfone, $(ClCH_2CH_2)_2S(=O)_2$ [46]. The sulfoxide is as toxic and as powerful a vesicant as HD and the sulfone is relatively non-toxic [46]. Loss of HCl along with oxidation to give divinyl sulfone $\{(H_2C{=}CH)_2\text{-}S(=O)_2$ has also been observed [48].

Only one reference to a laboratory study of hydrolysis of HT was found in the literature [47]. This study was aimed at hydrolyzing HT so that the hydrolysis products may be studied for biodegradation. The products of hydrolysis are listed in Tables F.2.1-3 and F.2.1-4. In natural waters similar products may be formed although more slowly than in the case of HD because of virtual insolubility of HT in water.

Terrestrial Fate

When sulfur is released into soils it is primarily lost by volatilization as indicated by its Henry's Law constant [4]. If there is any groundwater present, mustards will sink and they cannot evaporate from the depths and persist for years [4]. Volatilization from soil is dependent upon temperature, air speed, and soil type. Surface deposited HD is predicted to evaporate in 1100 to 2200 hours at 0°C and in 30 to 50 hours at 25°C [49]. Persistence in soil at low temperature is because HD freezes below 15°C. Norwegian field tests showed that HD deposited on snow disappeared after 2 weeks [2]. Studies conducted by Sanches et al. show that HD evaporates faster than sarin and deposits back to soil more slowly [1]. Release and deposition of HD from soil depends on type of soil and moisture content of the soil. HD also degrades in soil via hydrolysis and yields the same products as in coucous hydrolysis [23]. Since evaporation and deposition rates for HD depend upon the soil type [1] and moisture content, sorption probably plays an important role in its fate and transport.

Fate of Degradation Products of Mustards

The intermediate products of hydrolysis of HD or aggregates listed in the table above will persist only if there is insufficient water. These compounds will degrade to thiodiglycol and hydrochloric acid and to minor quantities of 1,4-dithiane and 1,4-oxathiane.

Thiodiglycol is completely miscible with water. Any TDG released into soil will be transported by groundwater. Because of its miscibility with water it will not sorb to soils and organic matter in soils [63]. It has a very low Henry's Law constant (1.85×10^{-9} atm-m^3/mol) [69]. Therefore, it will not volatilize from water and soil. Any TDG that enters the atmosphere will degrade by reaction with photochemically generated hydroxyl radicals in air and has a half-life of 13.3 hours [29].

TDG in water is oxidized to the sulfoxide, $(HOCH_2CH_2)_2SO$. In the presence of sunlight the sulfone will further oxidize to the sulfone, $(HOCH_2CH_2)_2SO_2$ [74].

HD is expected to biodegrade in soil by oxidation to its sulfoxide and sulfone and also by reduction via removal of the chlorine atoms or hydrogen chloride [17]. Since HD is hydrophobic microorganisms may not be able solubilize HD and direct degradation of HD is

expected to be slow. However, the hydrolysis products of mustard TDG and its oxidized forms have been shown to undergo biodegradation by bacteria, (e.g., *pseudomonas picketti* isolated from soils in Maryland), to carbon dioxide and sulfate under aerobic conditions. Since these bacteria are found naturally it is likely that HD will hydrolyze to TDG and TDG and then biodegraded by the bacteria. The hydrolysis products of HT are expected to behave similarly.

The minor byproducts, of HD hydrolysis are 1,4-oxathiane and 1,4-dithiane compounds thioxane has a low Henry's Law constant (2.56 x 10-7 atm-m3/mol) and is expected to volatilize from dry soil and slowly from water. Any thioxane in air will degrade by reaction with hydroxyl radicals and has a half-life of 4.6 hours [29]. It has moderate solubility in water and will not persist in soil. Oxathiane does not hydrolyze in water and is expected to biodegrade [76]. No environmental fate data were available for dithiane.

Mustard degradation pathway is shown in Figure F.2.1-1.

Table F.2.1-1. Chemical Identification Information—Sulfur Mustard

CAS Registry No.	505-60-2, 69020-37-7
Type	Vesicant (blistering) agent
Molecular Formula	$C_4H_8Cl_2S$
Molecular Weight	159.1
Other Hazardous Chemicals in Mixture	H, HD, and HT all contain the same toxic chemical, bis(2-chloroethyl)sulfide. H is made by the Levinstein process, resulting in approximately 70% bis(2- chloroethyl)sulfide and 30% sulfur impurities. HD is the purified form (distilled mustard). HT is 60% HD and 40% bis(2-(2-chloroethylthio)ethyl) and is the most potent and environmentally stable blistering agent of all three.

Table F.2.1-2. Chemical Identification Information—Mustard-T Mixture

CAS Registry No.	No information
Type	Vesicant (blistering) agent
Molecular Formula	HD: $C_4H_8Cl_2S$, T: $C_8H_{16}C1_2OS_2$
Molecular Weight	HD: 159.1, T: 263
Other Hazardous Chemicals in Mixture	Bis(2-chloroethyl)sulfide (HD) (60%), bis(2-(2-chloroethylthioethyl) ether) (T) (40%)

Table F.2.1-3. Physical-Chemical Properties—Sulfur Mustard

Physical Form/Color	Colorless, oily liquid, forming crystals on freezing		
Odor	Sweet, garlic-like (distilled form; HD); rotten egg smell with excess sulfur content. The odor threshold ranges from 0.0006 to 0.0013 mg/m^3; however, the sense of smell is obliterated in a few seconds once in contact.		
Relative Vapor Density (to air)	5.4 to 5.5		
Vapor Pressure	0.072 mm Hg at 20°C (low volatility potential)		
Boiling Point	217°C		
Henry's Law Constant, K_H	2.4 x 10^{-5} atm-m^3/mol		
Log K_{ow}	1.37		
Freezing Point	14.4°C – 15°C		
Density or Specific Gravity	1.27 g/mL		
Flash Point	104°C		
Stability	Stable in steel or aluminum containers		
Flammability/Combustibility	Combustible when exposed to heat or flame. Can be ignited by explosive charge. Material itself only burns with difficulty. Prolonged exposure to heat/fire may cause tank to rupture and rocket. Not flammable because it does not give off sufficient vapor (that is, flash point is above 100°C).		
Decomposition Temperature	149 to 177°C		
Thermal Decomposition Products	When heated, forms fumes of sulfur oxides and chlorides; HCl thiodiglycol		
Water Solubility	0.68 to 0.92 g/L		
Products of Hydrolysis	**Product**	**Formula**	**CAS No.**
	Sulfur mustard-thiodiglycol aggregate	$C_8H_{18}ClO_2S_2.Cl$	64036-91-5
	Sulfur mustard-thiodiglycol-thiodiglycol aggregate	$C_{12}H_{28}O_4S_3.2Cl$	64036-79-9
	Hemimustard-thiodiglycol aggregate	$C_8H_{19}S_2O_3.Cl$	64036-92-6
	Hydrochloric acid	HCl	7647-01-0
	Thiodiglycol	$(HOCH_2CH_2)_2S$	111-48-8
	1,4-Dithiane	$C_4H_8S_2$	505-29-5
	1,4-Thioxane	C_4H_8OS	
	Thiodiglycol sulfoxide	$(HOCH_2CH_2)_2S{=}O$	
	Thiodiglycol sulfone	$(HOCH_2CH_2)_2S){=}O)_2$	

Table F.2.1-4. Physical-Chemical Properties—Mustard-T Mixture

Physical Form/Color	Highly viscous, clear to pale yellow liquid		
Odor	Garlic-like		
Relative Vapor Density (to air)	6.92		
Vapor Pressure	0. 104 mm Hg at 25°C		
Boiling Point	Above 228°C		
Henry's Law Constant, K_H	Not available		
Log K_{ow}	Not available		
Freezing Point	0.0 to 1.3°C		
Density or Specific Gravity	1.24 g/mL		
Flash Point	Approximately 100°C		
Stability	Stable at ambient temperature; persistent agent depending on pH and moisture		
Water Solubility	Practically insoluble		
Flammability/Combustibility	No information		
Decomposition Temperature	165 to 185°C		
Thermal Decomposition Products	May produce hydrogen chloride and sulfur oxides in a fire		
Hydrolysis Products	**Product**	**Formula**	**CAS No.**
	Thiodiglycol	$(HOCH_2CH_2)_2S$	111-48-8
	Dihydroxy-T	$(HO\text{-}CH_2CH_2\text{-}S\text{-}CH_2CH_2)_2O$	N/A
	Dihydroxy-Q	$HO\text{-}CH_2CH_2\text{-}S\text{-}CH_2CH_2\text{-}S\text{-}CH_2CH_2\text{-}OH$	N/A
	1,4-Dithiane	$C_4H_8S_2$	505-29-5
	1,4-Thioxane	C_4H_8OS	15981-15-1

N/A: Not Available

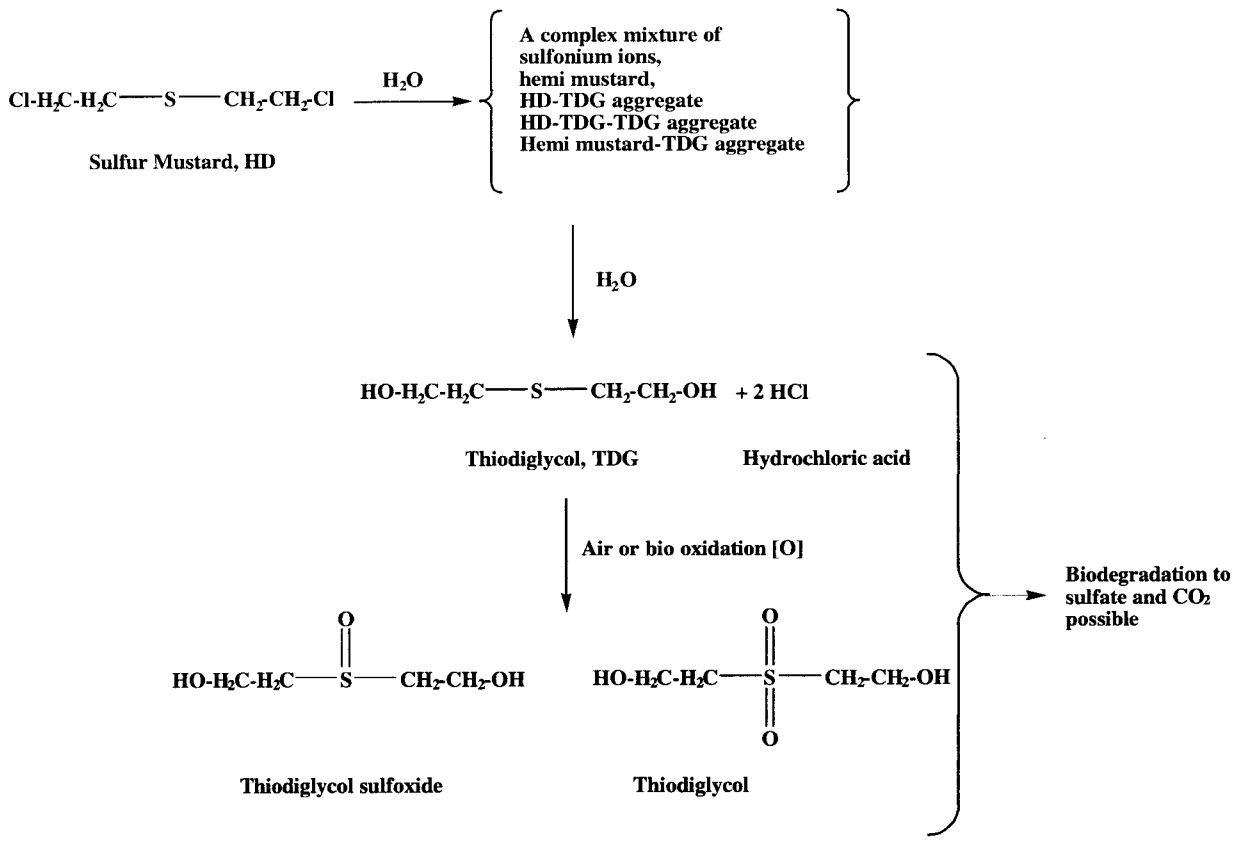

Figure F.2.1-1. Degradation of Sulfur Mustard, HD, in Water and Soil

F.2.2 Nitrogen Mustards (HN-1, HN-2, and HN-3)

Synonyms: dichlorotriethylamine; 2,2'-dichloro-n-methyldiethylamine; 2,2',2''-trichlorotriethylamine

F.2.2.1 Summary

Nitrogen mustards are a class of vesicants composed of HN-1, HN-2, and HN-3. They are similar to HD in their properties and effects. All three compounds are very slightly soluble in water and undergo rapid degradation in nature.

F.2.2.2 Chemical Identity

The nitrogen mustards are derivatives of ammonia hydrogen atoms in ammonia have been replaced by alkyl and chloroalkyl groups. In each of these agents, nitrogen is the central atom. Table F.2.2-1 presents the relevant chemical identity information for the nitrogen mustards.

F.2.2.3 Physical-Chemical Properties

Summaries of physical and chemical properties are presented in Tables F.2.2-2 through F.2.2-4.

F.2.2.4 Environmental Fate and Transport

Atmospheric Fate

No literature was found on the fate of these compounds in air. HN-1 and HN-2 closely parallel HD in the variation in their volatilities with temperature. HN-3 has lower volatility than HD and no dangerous concentrations can develop in the atmosphere [56]. It is unlikely that these compounds will react with moisture in air. After condensation on a surface they may hydrolyze to the corresponding ethanolamines [52]. Amines and ethanolamines are very good radical scavengers [51] and they will react with hydroxyl radicals in air and undergo secondary photodegradation.

Aquatic Fate

All three nitrogen mustards are denser than water [52] and will sink in groundwater as HD does. They may form what are known as "dichlorocyclic dimers," dissolve in groundwater, and hydrolyze [31,53]. These amines may be protonated in acidic groundwater and form quaternary ammonium salts which are soluble in water and transported by groundwater. If water pH rises above 7, the original amines precipitate out as oily liquids [56]. No information on volatilization out of water is available. It is highly unlikely HN-3 would volatilize although HN-1 and HN-2 may in turbid waters.

Very little information on the chemistry of HN-1, HN-2, and HN-3 in water is available [52,56,57]. The nitrogen mustards are basic amines and form stable salts with acids. For example, HN-3 forms the salt HN-3 hydrochloride, $[(ClCH_2CH_2)_3NH]^+Cl^-$, which is indefinitely stable in the solid state and in water providing pH is below 5. HN-1 and HN-2 hydrolyze more rapidly than HN-3 or the sulfur mustards. The route of hydrolysis is quite complex and its discussion is beyond the scope of this document. Ultimately, HN-1 and HN-2 hydrolyze losing the two chloride ions in successive steps to form bis(2-hydroxyethyl)ethyl amine and (2-hydroxyethyl)methyl amine respectively. Similarly, HN-3 hydrolyzes to triethanolamine. These mustards form dimeric quarternary ammonium chlorides with ease in

the presence of water and form crystalline solids. These solids eventually dissolve in water and convert to the ethanolamines as the end product [31]. Half-life for HN-1 hydrolysis is about 12.5 days at 5°C [43]. At pH greater than 7 the rate of hydrolysis is accelerated [56]. The rate of hydrolysis is diminished in acidic waters because of formation of quarternary ammonium salts. The hydrolysis products are soluble in water and will be transported by groundwater. Hydrolysis products are listed in the tables below.

Terrestrial Fate

There is no literature on the fate of nitrogen mustards in soil. These are amines and as discussed earlier, amines have a tendency to be sorbed to surfaces of silicate soils and partition between soil and water depending upon the pH. Once partitioned into water they will hydrolyze. There is no data on volatilization of these compounds from soils.

Fate of Degradation Products of HN-1, HN-2, and HN-3

No information on the fate of the HN-1 and HN-2 hydrolysis products were found. The fate of bis(2-hydroxyethyl)ethylamine and bis(2-hydroxyethyl)methylamine will tend to follow that of triethanolamine as they are very similar compounds. Triethanolamine is miscible with water. It has a very low vapor pressure [77] and a high boiling point (340°C). Therefore, it will not volatilize from water and soil. Although it may sorb to dry soil it will be leached by groundwater and will not persist. It will form quarternary ammonium salts if the soil and water are acidic. It readily absorbs carbon dioxide from air and forms a salt. Any triethanolamine in air will similarly react with carbon dioxide and deposit back to earth. Ethanolamines are very good radical scavengers [51] and will also degrade in the environment by reaction with photochemically generated hydroxyl radicals.

Triethanolamine biodegrades readily as microorganisms utilize nitrogen and carbon from this compound as nutrients. Biodegradation half-life of triethanolamine ranges from half an hour to 2 days depending upon the type of soil. In river water, it was found to be about half a day. [78]. Triethanolamine also undergoes anaerobic biodegradation to yield acetate and ammonium salts.

The nitrogen mustard degradation pathway is shown in Figure F.2.2-1.

Table F.2.2-1. Chemical Identification Information—Nitrogen Mustards

	HN-1	HN-2	HN-3
CAS Registry No.	538-07-8	51-75-2	555-77-1
Type	Vesicant (blistering) agent	Vesicant (blistering) agent	Vesicant (blistering) agent
Molecular Formula	$(ClCH_2CH_2)_2NC_2H_5$	$(ClCH_2CH_2)_2NCH_3$	$C_6H_{12}Cl_3N$
Molecular Weight	170.1	156.1	204.5
Other Hazardous Chemicals in Mixture	Not applicable	Not applicable	Not applicable

Table F.2.2-2. Physical-Chemical Properties—Nitrogen Mustard HN-1

Physical Form/Color	Pale amber to yellow oily liquid		
Odor	Faint fishy or musty odor		
Relative Vapor Density (to air)	5.9		
Vapor Pressure	0.25 mm Hg at 25°C		
Boiling Point	194°C at 760 mm Hg		
Henry's Law Constant, K_H	Not available		
Log K_{ow}	Not available		
Freezing Point	-34°C		
Density or Specific Gravity	1.083 g/mL		
Flash Point	No immediate danger of fire or explosion		
Stability	Adequate for use in munitions; unstable with respect to heat and light, dimerize in polar solutions		
Water Solubility	Very slightly soluble and increases with decreasing temperature		
Flammability/Combustibility	No information (see "Flash Point")		
Decomposition Temperature	Before boiling point is reached (below 194°C)		
Thermal Decomposition Products	Quaternary ammonium salts		
Products of Hydrolysis	**Product**	**Formula**	**CAS No.**
	Bis(2-hydroxy-ethyl)ethylamine	C_2H_5 $[N(CH_2CH_2OH)_2]$	139-87-7

Table F.2.2-3. Physical-Chemical Properties—Nitrogen Mustard HN-2

Physical Form/Color	Pale amber to yellow oily liquid		
Odor	In dilute concentrations: soap or fish. In high concentrations: fruity		
Relative Vapor Density (to air)	5.4		
Vapor Pressure	0.29 mm Hg at 20°C		
Boiling Point	75°C at 15 mm Hg		
Henry's Law Constant, K_H	Not available		
Log K_{ow}	Not available		
Freezing Point	-65 to –60°C		
Density or Specific Gravity	1.118 g/mL		
Flash Point	No immediate danger of fire or explosion		
Stability	Adequate for use in munitions; unstable with respect to heat and light, dimerize in polar solutions		
Water Solubility	13,000 ppm at ambient room temperatures		
Flammability/Combustibility	No information (see "Flash Point")		
Decomposition Temperature	Before boiling point is reached (below 194°C)		
Thermal Decomposition Products	Quaternary ammonium salts		
Products of Hydrolysis	**Product**	**Formula**	**CAS No.**
	Bis(2-hydroxy-ethyl)methyl amine	CH_3 $[N(CH_2CH_2OH)_2]$	105-59-9

Table F.2.2-4. Physical-Chemical Properties—Nitrogen Mustard HN-3

Physical Form/Color	Dark to bright yellow liquid		
Odor	Faint odor of fish and soap; none when pure		
Relative Vapor Density (to air)	7.1		
Vapor Pressure	0.011 mm Hg at 25°C		
Boiling Point	144°C at 15 mm Hg (256°C - calculated)		
Henry's Law Constant, K_H	Not available		
Log K_{ow}	Not available		
Freezing Point	-3.7°C		
Density or Specific Gravity	1.235 g/mL		
Flash Point	No immediate danger of fire or explosion		
Stability	Agent darkens and deposits a crystalline solid in storage; persistent in soil and on surfaces		
Water Solubility	0.08 g/L		
Flammability/Combustibility	Thermal decomposition may become explosive; polymerized components present an explosion hazard in open air		
Decomposition Temperature	150°C		
Thermal Decomposition Products	Products of combustion: CO_2, HCl, Cl_2, N_2, and water		
Products of Hydrolysis	**Product**	**Formula**	**CAS No.**
	Triethanolamine	$N(CH_2CH_2OH)_3$	102-71-6

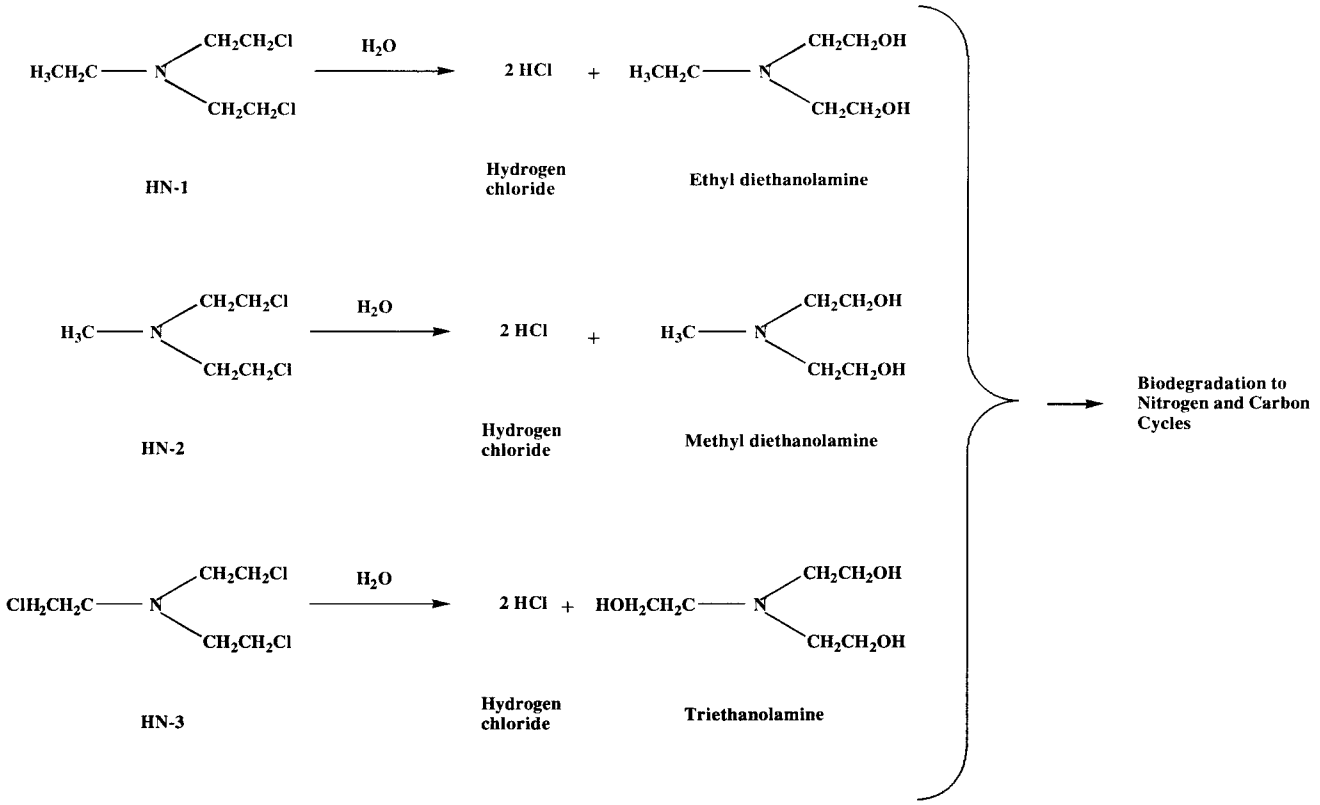

Figure F.2.2-1. Degradation of Nitrogen Mustards in Water and Soil

F.2.3 Lewisite (L) and Lewisite-Mustard Mixture (HL)

Synonyms: (2-chloroethenyl) arsenous dichloride

F.2.3.1 Summary

Lewisite (L) is a potentially lethal arsenical vesicant (blistering) agent. It produces toxic, skin-blistering effects similar to those of distilled sulfur mustard (HD) and acts as a systemic poison. Lewisite-Mustard mixture (HL) is a mixture of lewisite and distilled mustard. Since lewisite reacts quickly with water, considerable degradation occurs. However, arsenic is retained in the environment in one form or another. The degradation of HL is expected to follow the routes of its components and the degradation of mustards has been discussed earlier in Section F.2.1.

F.2.3.2 Chemical Identity

Lewisite is an organo-arsenic halide. The toxicity of lewisite is due to its ability to combine with thiol groups, which are essential for the function of a variety of enzymes. Table F.2.3-1 shows the relevant chemical identification information.

F.2.3.3 Physical-Chemical Properties

Tables F.2.3-2 and F.2.3-3 present summaries of physical and chemical properties. Lewisite is a colorless to brown oily liquid. It has a significant vapor pressure of 0.39 mm/Hg at 20°C and is more volatile than HD. It is only slightly soluble in water. Its Henry's Law constant is 3.2×10^{-4} atm-m^3/mol and therefore, has the potential for significant volatilization from water and soils. Its Log K_{ow} is not estimated because of its rapid hydrolysis in water. Its density is 1.88 g/mL and is very much denser than water.

F.2.3.4 Environmental Fate and Transport

Regardless of the method of lewisite degradation (hydrolysis, oxidation, or other environmental degradation), the arsenic component will be retained. The following subsections discuss the atmospheric, aquatic and terrestrial fate of lewisite.

Atmospheric Fate

Lewisite is quite volatile and more so than HD. Lewisite hydrolyzes by reaction with moisture in the air to form 2-chlorovinyl arsenous and 2-chlorovinyl arsonic acids. These acids undergo wet-deposition back to earth. Lewisite absorbs light in the near UV region (200-350 nm) and has the potential for direct photolysis and reaction with photochemicallys formed hydroxyl radicals in air with a half-life of about 1.2 days [34].

Aquatic Fate

Because of its high Henry's Law constant lewisite volatilizes significantly from water. Lewisite hydrolyzes by reaction with water [50,54]. Hydrolysis competes with volatilization. Unlike HD, even though lewisite has a limited solubility of 0.5 g/L in water, it hydrolyzes rather rapidly [41]. In slightly acidic solutions lewisite undergoes a fast reversible reaction to give 2-chlorovinyl arsenous acid [20,54, 41]. The arsenous acid is also a vesicant. The arsenous acid is slowly oxidized to the 2-chlorovinyl arsonic acid [41]. The arsenous acid can

also form 2-chlorovinyl arsenous oxide by dehydration (loss of water) [20]. The oxide undergoes polymerization to form an insoluble solid. The equilibrium lies to the left in acidic solutions and in alkaline solutions the equilibrium favors formation of the insoluble oxide. The 2-chlorovinyl arsenous oxide converts to the 2-chlorovinyl arsonic acid in the presence of oxidizers. No data is available on the lifetime of the 2-chlorovinyl arsenic compounds in the environment. Arsenic will persist in the environment in one form or another.

Lewisite exists in cis and trans isomeric forms. Rotation about the C=C is restricted because of the double bond and the vinyl chlorine atom and the arsenic atoms can be either on the same side (cis) of the double bond or on opposite sides (trans) of the double bond. In aqueous solutions the cis form undergoes phototransformation to the trans form [31, 41]. The cis and trans forms undergo hydrolysis under alkaline conditions to give different products [20, 41]. The cis form gives acetylene and arsenite salts (for e.g., Na_3AsO_3,). The trans form gives vinyl chloride and arsenite salts.

The products of degradation of lewisite are shown in the Table-F.2.3-2.

Terrestrial Fate

There are no data on soil adsorption of lewisite. Lewisite on soil can volatilize rapidly [41]. Because of its limited solubility in water it can persist in dry soils and sands [55]. Soil retained lewisite undergoes hydrolysis by reaction with soil moisture or groundwater as discussed above. Once the tri and pentavalent arsonic acids are formed they may form soluble salts in alkaline waters and be carried with groundwater. The arsenous oxide being insoluble, especially in alkaline medium, tends to persist.

Both lewisite and lewisite oxide may be slowly oxidized into 2-chlorovinylarsonic acid [41]. Microbial degradation in soil may occur via epoxidation of the C=C and reductive dechlorination [17]. Leaching of lewisite itself is not expected to be an important fate process but leaching of its acidic degradation products is likely.

A summary of the reactions of lewisite in the environment is shown in Figure F.2.3-1.

Table F.2.3-1. Chemical Identification Information—Lewisite and Lewisite-Mustard Mixture

CAS Registry No. (L)	541-25-3
Type	Vesicant (blistering) agent
Molecular Formula	$C_2H_2AsCl_3$
Molecular Weight	207.3
Other Hazardous Chemicals	Arsenic
CAS Registry No. (HL)	None
Type	Vesicant (blistering) agent

Table F.2.3-2. Physical-Chemical Properties—Lewisite

Physical Form/Color	Colorless, oily liquid when pure; may change to violet, brown, or green with impurities
Odor	Faint odor of geranium; very little odor when pure
Vapor Pressure	0.22 to 0.39 mm Hg at 20 °C
Boiling Point	190 °C at 760 mm Hg
Henry's Law Constant, K_H	3.2×10^{-4} atm-m^3/mol
Log K_{ow}	Not available
Freezing Point	-18 to 0.1°C, -1°C (trans), -45°C (cis)
Density or Specific Gravity	1.88 g/mL
Flash Point	None
Stability	Stable in steel or glass container
Water Solubility	0.5 g/L
Flammability/Combustibility	Does not burn or burns with difficulty; prolonged exposure of cylinders to fire or heat may result in violent rupturing or rocketing of the cylinders
Thermal Decomposition Products	Acetylene, acetylene chlorides, arsenic trichloride, arsenic trioxide, chlorine, methyl chloride, vinyl chloride, acetylene dichloride, arsenic oxychloride, chlorovinyl arsenous oxide

Products of Hydrolysis and oxidation

Product	Formula	CAS No.
2-Chlorovinyl arsenous acid	$ClCH{=}CH\text{-}As(OH)_2$	85090-33-1
Hydrochloric acid	HCl	7647-01-0
2-Chlorovilyl arsonic acid	$ClCH{=}CH\text{-}As(=O)(OH)_2$	64038-44-4
2-Chlorovinyl arsenous oxide	$ClCH{=}CH\text{-}AsO$	N/A
2-Chlorovinyl arsenous oxide polymer	$(ClCH{=}CH\text{-}AsO)_n$	N/A
Sodium or other arsenites	Na_3AsO_3	13464-37-4
Acetylene	HCCH	74-86-2
Vinyl chloride	$Cl\text{-}CH{=}CH_2$	75-01-4

N/A: Not Available

Table F.2.3-3. Physical-Chemical Properties—Mustard-Lewisite Mixture

Physical Form/Color	Dark oily liquid
Odor	Garlic-like
Relative Vapor Density (to air)	6.5
Vapor Pressure	0.248 mm Hg at 20°C
Boiling Point	Indefinite but below 190°C
Freezing Point	-25.4°C (pure); -42°C (plant purity; calculated)
Flash Point	No immediate danger of fire or explosion
Stability	Satisfactory in lacquered steel containers at ambient temperatures; persistent agent depending on pH and moisture
Water Solubility	Practically insoluble
Flammability/Combustibility	No information
Decomposition Temperature	Above 100°C
Thermal Decomposition Products	Toxic fumes of hydrogen chloride, sulfur oxides, and arsenic may be produced in a fire
Hydrolysis Products	See Sections F-2 and F-7.

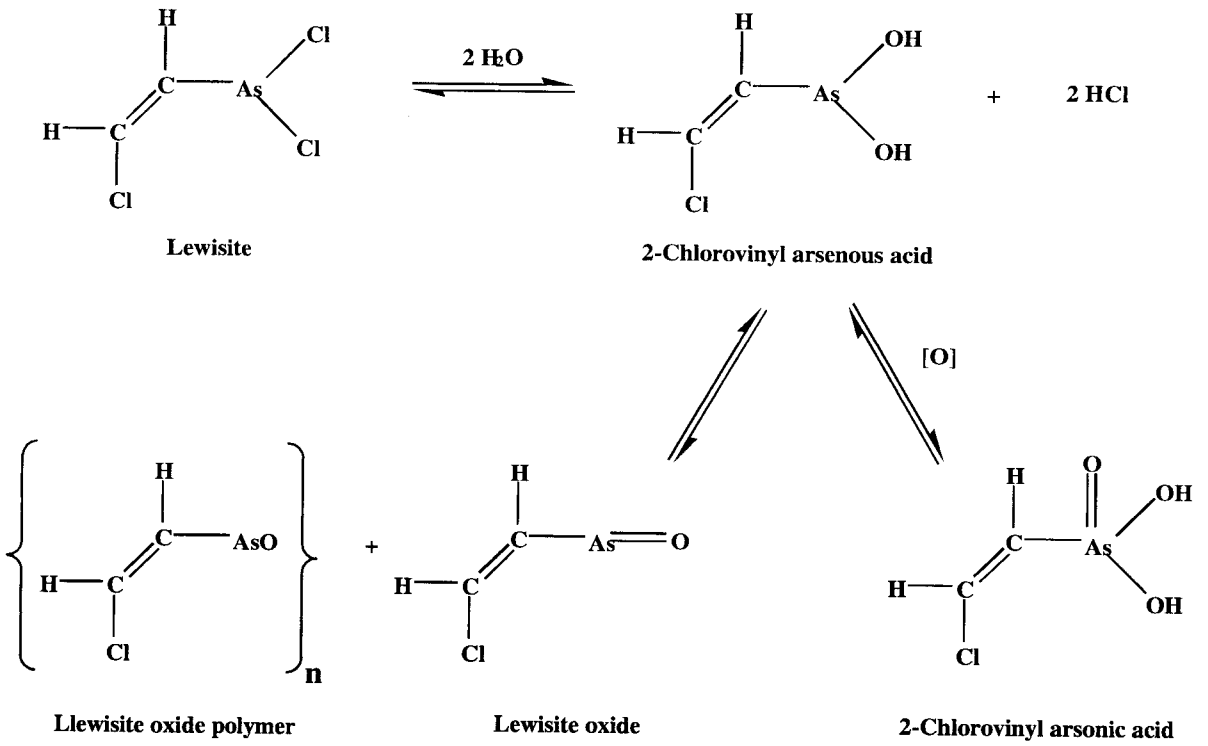

Figure F.2.3-1. Degradation of Lewisite, L, in Water and Soil

F.2.4 Sarin (GB)

Synonym: isopropylmethyl phosphonofluoridate)

F.2.4.1 Summary

Sarin (GB) is a lethal nerve agent. It is not a persistent chemical in the environment, because it rapidly evaporates and hydrolyzes.

F.2.4.2 Chemical Identity

Sarin is a lethal nerve (anticholinesterase agent) and it is the most potent G-type chemical nerve gas. Sarin is the most prevalent compound among the G-series nerve agents (sarin, soman, tabun) in the United States. G-series nerve agents are organophosphate ester derivatives of phosphoric acid. Table F.2.4-1 presents the relevant chemical identity information for sarin.

F.2.4.3 Physical-Chemical Properties

Table F.2.4-2 presents a summary of physical and chemical properties. Due to its high volatility, it is mainly an inhalation hazard.

F.2.4.4 Environmental Fate and Transport

Atmospheric Fate

Sarin has a significant vapor pressure of 2.9 mm/Hg at 25°C and is very volatile. When sarin is spilled on to dry soil or hard surfaces it will evaporate swiftly [1, 2, 3]. Once in the atmosphere sarin will slowly deposit back to earth. Volatilization half-life for sarin is 7.7 hours (fast evaporation, [4]). Sarin is miscible in water and physical removal from air by wet deposition is possible. Sarin tends to deposit back onto wet soil more slowly than onto dry soil because dry soil has greater sorption capability [1]. Duration of sarin residence in air is expected to be less than 10 hours [25].

No studies exist to show whether or not sarin undergoes direct photolysis in sunlight. It will degrade readily in the vapor phase by reaction with photochemically produced hydroxyl radicals with an estimated half-life of 10 hours [29]. One laboratory experiment [6] showed that chemical agent Soman (GD) underwent degradation to pinacolyl methylphosphonic acid (PMPA) upon irradiation. The extent of decomposition was greater in wet air than in dry air. This shows that photodegradation of little(s) also is very likely and is accompanied by hydrolysis. The product of such degradation would be isopropyl methylphosphonic acid (IMPA), which in turn would degrade to methylphosphonic acid (MPA) by loss of the iso-propoxy or the iso-propyl group. Methylphosphonic acid has a low vapor pressure. It is soluble in water and it would deposit back to earth. However, this may not be a significant fate process in the environment because the intensity of UV radiation near the surface is quite low.

Aquatic Fate

Sarin does not evaporate from water [25] as indicated by its low Henry's Law constant. Hydrolysis is the major decomposition reaction of sarin in water [7-20]. Sarin hydrolyzes in

two steps. In the first step the P-F bond hydrolyzes to give fluoride ion and isopropyl methylphosphonic acid (IMPA). IMPA then hydrolyzes more slowly to methylphosphonic acid (MPA) by loss of the isopropoxy group as isopropyl alcohol [7,8]. The products of hydrolysis are shown in the Table-F.2.4-2.

The hydrolysis of sarin is pH and temperature dependent [10,11,13]. The rate of hydrolysis increases with increase in acid (H^+) concentration or with increase in hydroxide ion (OH^-) concentration The rate is at a minimum near neutral conditions (pH = 7). In neutral waters sarin tends to persist. Half-life of sarin in neutral water has been shown to be in the range 193 to 312 hours [13,14,15]. At a pH of 12 the half-life is 3 seconds [15]. At lower temperatures (0^oC) and neutral pH half-life can be as long as 8300 hours indicating persistence. It can be shown that if neat sarin were spilled in water under warmer conditions it will take about 6.6 times the half-life (or 75 days in the worst case) for 99% degradation of sarin as a result of hydrolysis. This would result in the neat agent being degraded to below 1 ppm [20].

Sea, river, pond, and soil waters commonly contain metal ions (such as Ca^{2+} and Mg^{2+}) and these tend to speed up sarin hydrolysis by a factor of 2 to 4 [16]. Anions such as phosphate and nitrate do not affect the rate of hydrolysis. Presence of fluoride ions slows down the reaction [20].

No photochemistry of sarin in water was found in the literature. Kingery and Allen have reported that presence of metal radicals degrade organic phosphates in general [57].

Terrestrial Fate

When sarin is spilled onto soil the major route of loss is through evaporation because sarin is very volatile [17]. Volatilization of sarin is very significant and is faster than its hydrolysis in soil. [3,4]. Volatilization half-life of sarin is 7.7 hours [1]. However, if sarin is contained in bulk soil the evaporation rate is slower by several orders of magnitude [1]. Sorption to soil is not an important fate process because sarin dissolves in groundwater. Sarin is not persistent in soil as it is leached by water. Laboratory-field tests conducted in Norway have shown that in water and soil samples injected with the same amount of sarin water retained about 8% of sarin after a week whereas soil retained less than a millionth of one percent [18]. Retention and depletion of sarin from soil varies widely depending upon the types of soil, presence of vegetation, and climatic conditions [2,19]. Sarin on snowy ground can remain there as liquid because of low temperatures. [19]. In snowy conditions sarin is removed by a combination of evaporation (>50%) and hydrolysis (<15%) [19]. Snowfall can cover up liquid sarin and impede evaporation.

If considerable amount of moisture is present in soil sarin will partition into water and degrade by hydrolysis to IMPA and then slowly to MPA. Half-life of GB in certain types of soil was measured at 23 minutes [1], which is quite rapid. Thus, sarin does not persist in soils.

Sarin spilled on vegetation evaporates swiftly. Vegetation may take up sarin. However, sarin in vegetation would hydrolyze quickly. Experiments conducted at Dugway Proving Ground showed that 90% of sarin applied to grass disappeared in less than 6 days [26].

Fate of Sarin Degradation Products

The initial degradation product of sarin are fluoride ion and isopropyl methylphosphonic acid (IMPA). Fluoride ion will most probably precipitate out of groundwater as calcium fluoride. Soils can also bind fluoride ions at pH greater than 7. Soils with high calcium content will immobilize fluoride [65].

IMPA is a water-soluble acid and is transported by groundwater. It forms salts with metal ions such as Na^+ or Ca^+ under alkaline conditions (pH > 7). These salts are also water-soluble. IMPA does not volatilize from soil or water. It may strongly adsorb to soil [62]. IMPA slowly hydrolyzes in water to give isopropyl alcohol and methylphosphonic acid (MPA) with a half-life of about 14 days depending upon the pH of the soil and water [62].

MPA is quite stable in the environment because the P-CH_3 bond is quite strong [9,12,27]. It has been shown that MPA may degrade slowly to inorganic phosphate in aqueous solutions containing Ca^{2+} or Mg^{2+} ions. Formation of salts with these ions weakens the strong P-CH_3 bond and causes mineralization of MPA [58].

Phosphorus from organic phosphorus compounds and inorganic sources is an important nutrient for bacterial cultures. Bacterial degradation of organophosphonates, including sarin and soman, have been studied [59,60]. Strains of the bacteria *Pseudomonas testosteroni* have been known to aerobically metabolize organic phosphonates to yield alcohols, alkanes, and inorganic phosphate by means of the enzyme *phosphonatase.* IMPA is metabolized to consume phosphate and isopropyl alcohol and acetone are excreted [59-61]. The bacteria also metabolize MPA by means of the enzyme *C-P lyase* [59,60], consume phosphate (PO_4^{3-}), and release methane, methanol, formaldehyde, formic acid, and carbon dioxide [61]. It should be noted that bacterial degradation is strongly affected by types of soils, clays, and organic matter present in soil. Organic matter in soil can retain MPA and make it unavailable to the bacteria [59]. Prior presence of inorganic phosphate in soils can also impede biodegradation of organic phosphonates for the bacteria preferentially utilize inorganic phosphate. Soils usually contain other sources of phosphorus and thus biodegradation in soil may be severely impeded. However, this may be an important fate in waters, which has low phosphorus content.

Isopropyl alcohol is the other secondary degradation product. It is miscible with water. It has the potential to volatilize from water and soil. In soil or water it is oxidized to acetone [66]. Acetone will dissipate into the atmosphere. Because of its solubility in water it will not accumulate.

Sarin degradation is summarized in Figure F.2.4-1.

Table F.2.4-1. Chemical Identification Information—Sarin

CAS Registry No.	107-44-8
Type	Nerve agent
Molecular Formula	$C_4H_{10}FO_2P$
Molecular Weight	140.1
Other Hazardous Chemicals in Mixture	Not applicable

Table F.2.4-2. Physical-Chemical Properties—Sarin

Physical Form/Color	Colorless liquid		
Odor	Almost none in pure state		
Relative Vapor Density (to air)	4.9		
Vapor Pressure	2.9 mm Hg at 25°C		
Boiling Point	147°C at 760 mm Hg; 158°C, when pure		
Henry's Law Constant, K_H	5.34×10^{-7} atm-m^3/mol		
Log K_{ow}	0.15		
Freezing Point	-56°C		
Density or Specific Gravity	1.09 g/mL		
Flash Point	Nonflammable		
Stability	Fairly stable in steel containers at 65°C; stability improves with purity; unstable in presence of water		
Water Solubility	Miscible with water		
Odor	Almost none in pure state		
Flammability/Combustibility	May burn but does not ignite readily; may explode violently in heat of fire		
Decomposition Temperature	150°C		
Thermal Decomposition Products	Phosphoric acid, hydrogen fluoride, phosphorus pentoxide		
Hydrolysis Products	**Product**	**Formula**	**CAS No.**
	Isopropyl methylphosphonic acid (IMPA)	$(CH_3)P(=O)[OCH(CH_3)_2](OH)$	1832-54-8
	Hydrogen fluoride	HF	7664-39-3
	Methylphosphonic acid (MPA)	$(CH_3)P(=O)(OH)_2$	993-13-5
	Isopropyl alcohol	$(CH_3)_2CHOH$	67-63-0

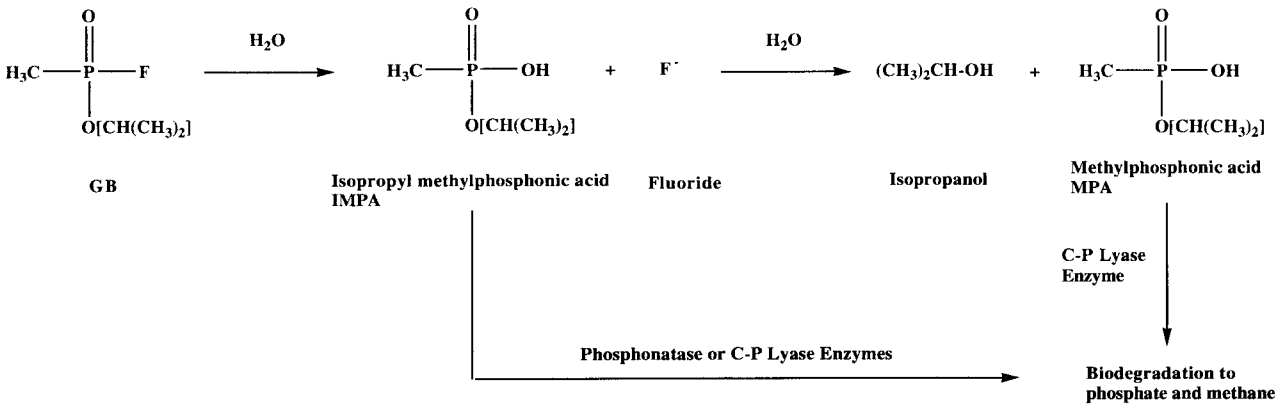

Figure F.2.4-1. Degradation of Sarin, GB, in Water and Soil

F.2.5 Soman (GD)

Synonym: pinacolyl methylphosphonofluoridate

F.2.5.1 Summary

Soman (GD) is a lethal nerve agent that exhibits low persistence in the environment by virtue of its volatility and hydrolysis.

F.2.5.2 Chemical Identity

Soman is a lethal nerve (anticholinesterase) agent. It is one of several G-series nerve agents, which are organophosphate ester derivatives of phosphoric acid. Although the United States did not produce soman, research was conducted to provide proper protection for soldiers against possible future use. Relevant chemical information for soman is presented in Table F.2.5-1.

F.2.5.3 Physical-Chemical Properties

Table F.2.5-2 lists a summary of physical and chemical properties. Soman is considered a nonpersistent agent, similar to sarin. However, soman is approximately five times less volatile than sarin (intermediate volatility).

F.2.5.4 Environmental Fate and Transport

Atmospheric Fate

Soman has a vapor pressure 0.4 mm/Hg at 25°C and it is volatile although to a lesser degree than sarin. There is no information in the literature on volatilization of soman and its subsequent fate. However, since soman is structurally very similar to sarin it will probably suffer similar fate. Once in air it will probably deposit back to earth at a rate greater than that of sarin because of it lower vapor pressure, higher molecular weight, and higher vapor density. One laboratory experiment [6] showed that chemical agent soman underwent degradation to pinacolyl methylphosphonic acid (PMPA) upon irradiation. The extent of decomposition was greater in wet air than in dry air. However, this may not be a significant fate process in the environment because the intensity of UV radiation near the surface is quite low.

Aquatic Fate

Hydrolysis is the major decomposition reaction of soman in water [7-20]. Soman hydrolyzes in two steps. In the first step the P-F bond hydrolyzes to give pinacolyl methylphosphonic acid (PMPA). PMPA then hydrolyzes more slowly to methylphosphonic acid (MPA) by loss of the pinacolyl group as pinacolyl alcohol [20]. The reaction rate is about 5 times slower than that of sarin. Soman has a half-life of 50 hours at a pH of 7.6 [20]. The products of hydrolysis are shown in Table F.2.5-2.

The hydrolysis of soman is pH and temperature dependent (20). The rate of hydrolysis increases with increase in acid (H^+) concentration or with increase in hydroxide ion (OH^-) concentration. The rate is at a minimum near neutral conditions (pH = 7). At a pH >10 soman hydrolyzes in minutes.

Sea, river, pond, and soil waters commonly contain metal ions such as Ca^{2+} and Mg^{2+}) and these tend to speed up the sarin hydrolysis by a factor of 2 to 4 [22]. Anions such as phosphate and nitrate do not affect the rate of hydrolysis. Presence of fluoride ions slows down the reaction [22].

No photochemistry of soman in water was found in the literature.

Terrestrial Fate

Soman behaves much like sarin in soil [2,18,19]. Soman was found to be more persistent in water than in soil. This is attributed to evaporation from soil. This is consistent with the conclusion drawn from Henry's Law constant for soman. Laboratory-field tests conducted in Norway have shown that in water and soil samples injected with the same amount of soman, water retained about 0.2% of soman after a week whereas soil retained less than 0.007% [18]. These data also show that soman tends to sorb to soil more so than in sand. Norwegian [2,18, 19] and Canadian [21] studies show that soman that is retained in various types of soils is hydrolyzed by groundwater to PMPA and eventually to MPA and pinacolyl alcohol. Studies have shown that 75% of soman on spilled on vegetation will evaporate in less than an hour and 99% degradation of retained soman will occur in 3 days [25].

Fate of Degradation Products of Soman

The initial degradation product of soman are fluoride ion and pinacolyl methylphosphonic acid (PMPA). PMPA is a water-soluble acid and is transported by groundwater. It forms salts with metal ions such as Na^{+} or Ca^{2+} under alkaline conditions (pH > 7). These salts are also water-soluble. PMPA does not volatilize from soil or water as indicated by its low Henry's Law constant [63]. It may strongly adsorb to soil [62]. PMPA slowly hydrolyzes in water to give methylphosphonic acid (MPA) with a half-life of about 14 days [62] depending upon the pH of the soil and water. The fate of MPA the secondary product has been discussed above in Section-F.4.4.3. PMPA may also be biodegraded as in the case of IMPA (see Section-F.4.4.3) with consumption of phosphate and release of pinacolyl alcohol.

Pinacolyl alcohol may volatilize as indicated by its high Henry's Law constant [63]. It is moderately soluble in water. It has a low Log K_{ow} (1.48) and may partition from soil and water into organic matter in the environment. Any pinacolyl alcohol that volatilizes is degraded by reaction with photochemically generated hydroxyl radicals in air and has an estimated half-life of 1.8 days [29]. Sorption to soil is not important because of its solubility in water. Pinacolyl alcohol may be metabolized by bio-oxidation to pinacolone [64] which is a rather stable compound.

Soman degradation pathway is summarized in Figure F.2.5-1.

Table F.2.5-1. Chemical Identification Information—Soman

CAS Registry No.	96-64-0
Type	Nerve agent
Molecular Formula	$C_7H_{16}FO_2P$
Molecular Weight	182.2
Other Hazardous Chemicals in Mixture	Not applicable

Table F.2.5-2. Physical-Chemical Properties—Soman

Physical Form/Color	Colorless liquid		
Odor	Fruity; camphor when impure		
Relative Vapor Density (to air)	6.33		
Vapor Pressure	0.4 mm Hg at 25°C C		
Boiling Point	167 to 200°C		
Henry's Law Constant, K_H	4.56 x 10^{-6} atm-m^3/mol		
Log K_{ow}	1.02		
Freezing Point	-70 to –42°C		
Density or Specific Gravity	1.02 g/mL		
Flashpoint	121°C (open cup)		
Stability	Less stable than tabun or sarin		
Water Solubility	Moderate (<15 g/L, 20 g/L at 20°C)		
Flammability/Combustibility	May burn but does not ignite readily; may explode violently in heat of fire		
Decomposition Temperature	130°C		
Thermal Decomposition Products	Phosphate oxides and fluorides		
Hydrolysis Products	**Product**	Formula	CAS No.
	Pinacolyl methylphosphonic acid	$(CH_3)P(=O)[OCH(CH_3)$-$C(CH_3)_3](OH)$	616-52-48
	Hydrogen fluoride	HF	7664-39-3
	Methylphosphonic acid	$(CH_3)P(=O)(OH)_2$	993-13-5
	Pinacolyl alcohol	$(CH_3)_3C(CH3)CHOH$	464-07-3

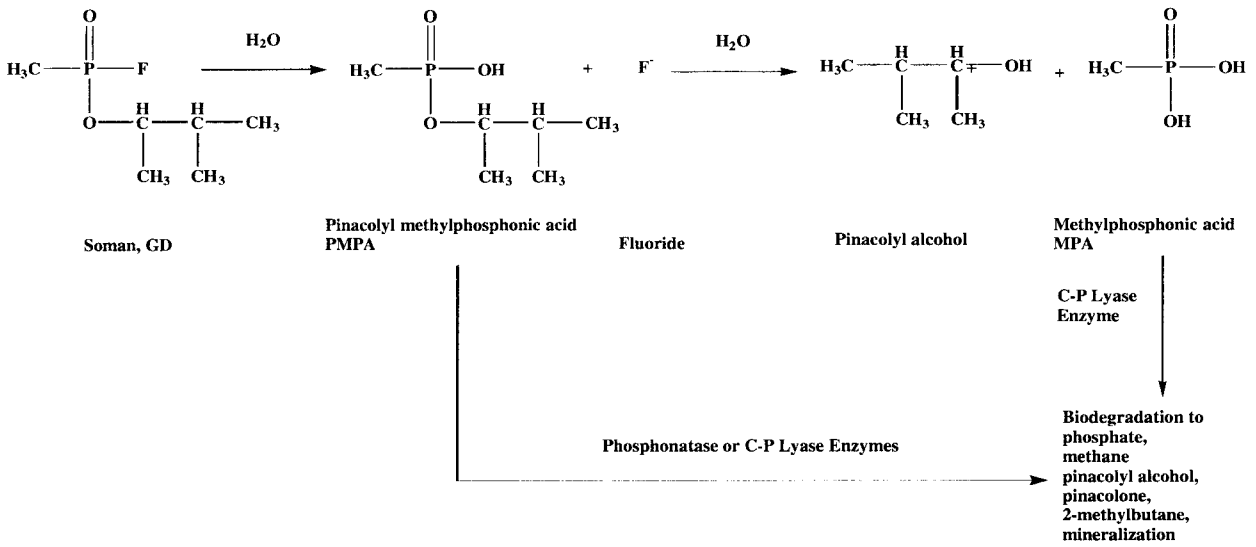

Figure F.2.5-1. Degradation of Soman, GD, in Water and Soil

F.2.6 Tabun (GA)

Synonym: ethyl n,n-dimethylphosphoramidocyanidate

F.2.6.1 Summary

Tabun (GA) is a lethal nerve agent that is readily degraded in the environment by virtue of its ready hydrolysis.

F.2.6.2 Chemical Identity

Tabun is a lethal nerve (anticholinesterase) agent. It is one of several G-series nerve agents, which are organophosphate ester derivatives of phosphoric acid. Tabun was the first nerve agent developed for military use and was replaced by sarin in the U.S. arsenal. Table F.2.6-1 presents the relevant chemical identity information for tabun.

F.2.6.3 Physical-Chemical Properties

Table F.2.6-2 presents a summary of physical and chemical properties. Although environmental degradation may be fairly rapid, one of the primary considerations for tabun during an accidental release is that it is more persistent than sarin in the environment. Furthermore, its hydrolysis may produce toxic hydrogen cyanide fumes.

F.2.6.4 Environmental Fate and Transport

Atmospheric Fate

Considering its high boiling point (245°C), vapor density, and low vapor pressure it would volatilize to a far lesser degree than the other G agents. Its volatility is about 1/20th that of water. Tabun is significantly soluble in water and removal from the air by wet deposition is possible. Degradation is rapid (half-life estimated at 4.8 hours) in the vapor phase by reaction with photochemically produced hydroxyl radicals [29].

Aquatic Fate

Tabun does not volatilize from water as indicated by its low Henry's Law constant. It will decompose in water by hydrolysis [27]. The products of hydrolysis depend upon pH. Base hydrolysis is the predominant reaction pathway [27]. The pH dependent products are shown in the Table F.2.6-2 and in Figure F.2.6-1.

Half-life of tabun is also pH and temperature-dependent [28]. Half-life is a maximum of 9 hours at pH 7. In very acidic or alkaline conditions, half-life is as low as 0.3 hours at 20°C. As with sarin and soman, tabun hydrolysis is sped up in the presence of metal ions such as Cu^{2+}, Ca^{2+}, or Mg^{2+}, which are commonly found in the environment. Anions such as phosphate, sulfate, etc. generally do not have any effect on the rate of tabun hydrolysis. The phosphorus containing hydrolysis products eventually hydrolyze further to phosphoric acid [27]. Formation of MPA is unlikely.

Terrestrial Fate

No direct literature was found for fate of tabun in soil. Compared to sarin, the volatility of tabun is significantly smaller. Thus, tabun spilled in soil is most likely to sorb to soil via the dimethyl-amino group and because of its significant solubility in water, groundwater will leach tabun from soil and hydrolyze it. No studies on biodegradation of tabun were found in the literature.

Table F.2.6-1. Chemical Identification Information—Tabun

CAS Registry No.	77-81-6
Synonyms	Ethyl n,n-dimethyl phosphoramidocyanidate, GA
Type	Nerve agent
Molecular Formula	$C_5H_{11}N_2O_2P$
Molecular Weight	162.1
Other Hazardous Chemicals in Mixture	Not applicable

Table F.2.6-2. Physical-Chemical Properties—Tabun

Physical Form/Color	Colorless to brownish liquid		
Odor	Faintly fruity; none when pure		
Relative Vapor Density (to air)	5.6		
Vapor Pressure	0.07 mm Hg at 25°C		
Boiling Point	247.5°C; 220 to 246°C at 760 mm Hg		
Henry's Law Constant	1.52×10^{-7} atm-m^3/mol		
Log K_{ow}	1.18		
Freezing Point	-50°C		
Density or Specific Gravity	1.08 g/mL		
Flash Point	78°C		
Stability	Stable in steel containers at ordinary temperatures		
Water Solubility	98 g/L at 25°C		
Odor	Faintly fruity; none when pure		
Flammability/Combustibility	Combustible (see "Thermal Decomposition Products")		
Decomposition Temperature	150°C		
Thermal Decomposition Products	Phosphorus pentoxide; hydrogen cyanide and nitrogen dioxide		
Hydrolysis Products	**Product**	**Formula**	**CAS No.**
Acidic hydrolysis	Ethylphosphoryl cyanidate	$(HO)\text{-}P(=O)(CN)(OC_2H_5)$	117529-17-6
	Dimethylamine	$(CH_3)_2NH$	124-40-3
Basic Hydrolysis	Ethyl N,N-dimethylamido phosphoric acid	$(CH_3)_2N\text{-}P(=O)\text{-}$	2632-86-2
	Ethanol	C_2H_5OH	64-17-5
	Cyanide salt	HCN or $(M^+)(CN^-)$	74-90-8
Other minor Products [27]	Phosphorocyanidate	$(HO)_3\text{-}P(=O)(CN)$	23852-43-9
	Dimethylphosphoramidate	$(HO)_3\text{-}P(=O)[N(CH_3)_2]$	33876-51-6
	Dimethylphosphoramide cyanidate	$(NC)\text{-}P(=O)(OH)[N(CH_3)_2]$	63917-41-9

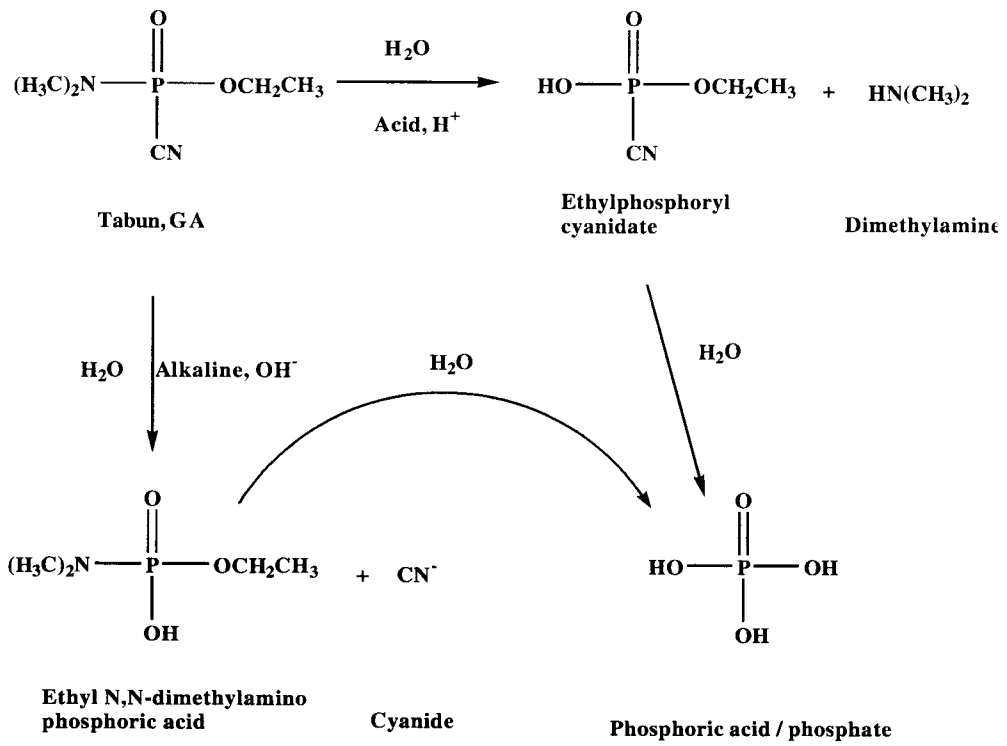

Figure F.2.6-1. Degradation of Tabun, GA, in Water and Soil

F.2.7 VX (O-Ethyl-S-(2-Diisopropylaminoethyl) Methyl Phosphonothiolate)

Synonyms: phosphonothioic acid, methyl-s-(2-bis(1-methylethylamino)ethyl)o-ethylester; venom X)

F.2.7.1 Summary

O-ethyl-S-(2-diisopropylaminoethyl) methyl phosphonothiolate (VX) is a lethal nerve agent. Degradation of VX in the environment may occur by evaporation, photochemical reactions, and hydrolysis; however, the rate of degradation is a function of ambient conditions. Furthermore, some of the degradation products are also toxic, less likely to degrade, and may exist for extended periods of time.

F.2.7.2 Chemical Identity

VX is an organophosphate compound. Table F.2.7-1contains the chemical identity information for VX.

F.2.7.3 Physical-Chemical Properties

Table **F.2.7-2** presents a summary of physical and chemical properties. VX is a relatively nonvolatile chemical, therefore, its dispersal following a release is not as extensive as G-series agents.

F.2.7.4 Environmental Fate and Transport

Atmospheric Fate

Release from munitions containing VX into the atmosphere results in the formation of droplets, which are subject to gravitational settling. VX from resulting droplets may reenter the atmosphere via evaporation; however, this is a very slow process because the vapor pressure of VX is very low [29]. The rate of VX evaporation is also a function of droplet size, temperature, humidity, and wind speed. VX has a volatilization half-life of 13,000 hours (very slow vaporization) from surface soils and from bulk soils it is about 10 times slower than sarin [4]. There is no direct literature on atmospheric photodegradation of VX. It is reported that a VX-simulant $[CH_3CH_2O][CH_3CH_2S]P[S][CH_3]\}$ and similar pesticides are resistant to photodegradation [20]. Also, VX does not absorb UV radiation of wavelength greater than 290-nm primary photodegradation does not appear to be a significant fate. However, VX can react with photochemically produced hydroxyl radicals in air and degrade with an estimated half-life of 0.24 days [29].

Aquatic Fate

VX does not volatilize from water as indicated by its low Henry's Law constant. It tends to sink into water and is adsorbed by sediment. Partitioning between soil and water may be quite slow [32]. VX hydrolyses slowly in comparison with the G type nerve agents because of its limited solubility in water [31]. Even though its solubility increases at lower temperature, lower temperatures invariably lower reaction rates [20].

The products formed depend upon the pH of the reaction medium. VX is relatively more stable than the G agents under acidic conditions. The products of hydrolysis are shown in Table-F.2.7-2 and Figure F.2.7-1.

Half-life of VX in water is pH and temperature dependent. In the pH range of 6-10 and at 25°C, half-life varies from 2327 hours to 41 hours [33]. At lower winter temperatures (4°C) the half-life can be as long as 2 years [20]. In seawater, where the pH is 7.7-8, it takes about 3.3 years for 99.9% of VX to decompose at 5°C and about 2.4 months at 25°C. Unlike in the case of G agents metal ions in water do not have any effect on the rate of hydrolysis.

Terrestrial Fate

VX is moderately persistent on bare ground, remaining at significant concentrations for approximately 2 to 6 days. VX can be more persistent than the G agents in soil [2, 26, 32]. It does not volatilize as easily as the G agents. Protonation of the amino group is favored under acidic conditions and VX may strongly adsorb to silicate soils that have acidic surfaces [32]. Because of it modest solubility in water partitioning between soil and water can be slow and depends on the pH and temperature of groundwater. Under acidic conditions VX is leached from soil and carried by groundwater and will eventually hydrolyze as described above.

VX degrades in a matter of days in moist soils rich in humidity and organic matter. For example, in field studies conducted at Carroll Island, MD [4], VX sprayed on soil degraded three orders of magnitude within 17-52 days to methylphosphonic acid. Norwegian studies have shown that VX can persist even after 4 weeks on snow in wintry conditions [2].

VX may also be assimilated by vegetation. Studies at Dugway have shown that certain roots such as alfalfa take up VX and it may persist there as indicated by the effects on test animals, which were fed alfalfa roots [24].

Fate of VX Degradation Products

Ethyl methylphosphonic acid (EMPA) is a primary degradation product of VX hydrolysis at pH less than 7. Like the degradation products of sarin and soman, EMPA is water soluble acid and is transported by groundwater (see Sections F.2.4 and F.2.5). Under alkaline conditions (pH > 7) it forms salts with metal ions such as Na^+ or Ca^{2+}. Calcium and magnesium salts may precipitate out of water and adhere to soils. EMPA itself can be sorbed to soils depending upon pH [62]. EMPA has a very low Henry's Law constant (5.2×10^{-9} atm-m^3/mol) and volatilization from soil and water is not an important process [69]. EMPA hydrolyzes to MPA and ethanol. Its half-life in soil and water is about 14 days [62] and this is a function of pH.

EMPA, like IMPA, is metabolized by bacteria via the enzyme *phosphonatase* to give ethanol, ethane, and methyl phosphonic acid (MPA) [58,70]. MPA further biodegrades via the enzyme *C-P lyase* to give inorganic phosphate and methane [58,70]. Any EMPA in the atmosphere is degraded by secondary photolysis reaction with hydroxyl radicals in air and this process has a half-life of 21.9 hours [29].

Ethanol is both a primary and a secondary degradation product of VX. Ethanol is miscible with water and will not accumulate. Ethanol can also dissipate into the atmosphere

from soils and surface waters. Microorganisms such as *escherichia-coli*, metabolize alcohols as carbon source [58].

Diisopropyl ethyl mercaptoamine is another primary degradation product of VX. No data on its environmental fate was found. However, it is known that this compound is oxidized to the disulfide, bis(diisopropylaminoethyl)disulfide, [R-S-S-R] which is very stable [71].

No literature on the fate of EA2192—a breakdown product of VX—in the environment was available. The compound EA2192 is formed from VX in the pH range 6-10. Most soils and groundwater have a pH range of 4-9. Thus, if VX is released into soil or water EA2192 can be formed. It is soluble in water and can be transported in groundwater. Laboratory studies on hydrolysis of VX in seawater (pH 7.7) have shown that EA2192 is very long-lived even at pH of 13 to 14 and it hydrolyzes about 3700 times more slowly than VX [72]. There are no reliable studies of its fate in soils. One study conducted in the Netherlands showed that EA2192 was detected one day after soils were injected with VX and it disappeared thereafter. This rapid disappearance in soil as opposed to that in water alone may be attributed to biodegradation.

VX degradation pathway is summarized in Figure F.2.7-1.

Table F.2.7-1. Chemical Identification Information—VX

CAS Registry No.	50782-69-9
Type	Nerve agent
Molecular Formula	$C_{11}H_{26}NO_2PS$
Molecular Weight	267.4
Other Hazardous Chemicals in Mixture	Not applicable

Table F.2.7-2. Physical-Chemical Properties—VX

Physical Form/Color	Amber colored oily liquid		
Odor	Odorless		
Relative Vapor Density (to air)	9.2		
Vapor Pressure	0.0007 mm Hg at 25°C		
Boiling Point	298°C		
Freezing Point	Below -51°C; -39°C (calculated)		
Density or Specific Gravity	1.0083 g/mL		
Henry's Law Contant, K_H	8.19×10^{-9} atm-m^3/mol		
Log K_{ow}	2.09		
Flash Point	159°C		
Stability	Relatively stable at ambient temperatures; unstabilized VX of 95% purity decomposes at a rate of 5% per month at 71°C		
Water Solubility	Moderate (30 g/L)		
Flammability/Combustibility	May burn but does not readily ignite; may explode violently in heat of fire		
Decomposition Temperature	Half-life of 36 hours at 150°C; 1.6 hours at 200°C; 4 minutes at 250°C; 36 seconds at 295°C		
Thermal Decomposition Products	Phosphoric acid, sulfuric acid, phosphorus pentoxide, nitrogen, and nitrogen dioxide		
Hydrolysis Products	**Product**	**Formula**	**CAS No**
pH < 7 or pH >10	Ethyl Methylphosphonic acid (EMPA)	$(C_2H_5O)P(=O)(CH_3)(OH)$	1832-53-7
	Diisopropyl ethyl mercaptoamine	$HSCH_2CH_2N[CH(CH_3)_2]$	5842-07-9
pH 7-10	S-(2-diisopropyl-aminoethyl)-methylphosphono-thiolate (EA2192)	$(HO)P(=O)(CH_3)$ $[SCH_2CH_2N[CH(CH_3)_2]$	73207-98-4
	Ethanol	CH_3CH_2OH	64-17-5

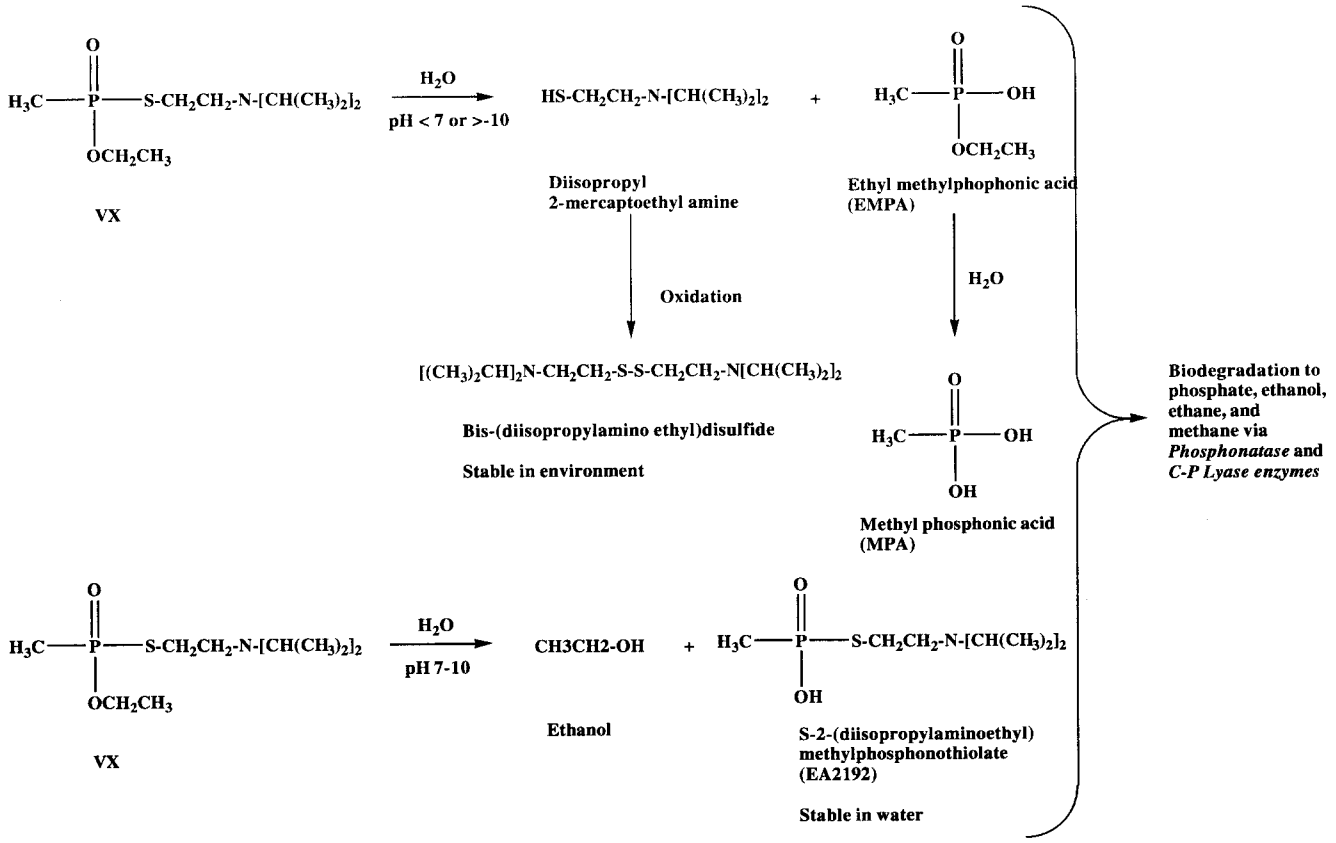

Figure F.2.7-1. Degradation of VX in Water and Soil

F.3 Industrial Chemicals

Industrial chemicals are those that are manufactured for and used in normal industrial operations or research and are not developed primarily for military purposes. U.S. and foreign militaries, however, have used some industrial chemicals in chemical weapons and programs because of their chemical properties.

F.3.1 Adamsite (DM)

Synonym: 10-chloro-5,10-dihydrophenarsazine

F.3.1.1 Summary

Adamsite (DM) is an industrial chemical that can cause extreme nausea and vomiting, respiratory tract irritation, and bodily discomfort subsequent to inhalation and ingestion. Adamsite can act as a vomiting agent (sternutator) because, in addition to being a strong irritant to the respiratory tract, it produces extreme nausea and vomiting. Although data are limited, adamsite is expected to be persistent in the environment. However, it contains arsenic and arsenic will prevail in the environment in one form or another.

F.3.1.2 Chemical Identity

Table F.3.1-1 presents the relevant chemical identity information for adamsite.

F.3.1.3 Physical-Chemical Properties

Table F.3.1-2 presents a summary of physical and chemical properties of adamsite.

F.3.1.4 Environmental Fate and Transport

Atmospheric Fate

Adamsite is a solid which, when heated, will form an aerosol [135]. Release of adamsite aerosol into the atmosphere results in droplet formation, which eventually settle on land and water surfaces. Data are limited on the degradation of adamsite; however, because its vapor pressure is very low [<0.00011 mm Hg at 25°C], it is not expected to significantly evaporate. In addition, water in the atmosphere may react with adamsite to form an oxide coating that prevents hydrolysis from occurring [135].

Aquatic Fate

Data on the aquatic fate of adamsite are limited. However, hydrolysis of the As-Cl bond to the As-OH is to be expected and since adamsite is sparingly soluble in water its hydrolysis is expected to be slow [135]. Furthermore, the hydrolysis product forms a protective layer on top of the solid adamsite and impedes hydrolysis of adamsite in bulk solid.

Terrestrial Fate

Data on the terrestrial fate of adamsite are limited. Adamsite is not expected to volatilize from soils [135]. Solid-phase adamsite is expected to be persistent in the terrestrial environment because it has low water solubility and it does not readily hydrolyze. Furthermore, when solid adamsite is covered with water in moist soils, a protective oxide coating is formed hindering further hydrolysis.

Table F.3.1-1. Chemical Identification Information—Adamsite

CAS Registry No.	578-94-9
Type	Industrial chemical
Molecular Formula	$C_{12}H_9AsClN$
Molecular Weight	277.6
Other Hazardous Chemicals in Mixture	Arsenic

Table F.3.1-2. Physical-Chemical Properties—Adamsite

Physical Form/Color	Light yellow to dark yellow-green solid
Odor	No pronounced odor; irritates nasal passages similar to pepper
Relative Vapor Density (to air)	9.6 (does not vaporize at 20°C)
Vapor Pressure	<0.00011 mm Hg at 25°C
Boiling Point	410°C
Freezing Point	195°C
Flash Point	None under usual conditions
Stability	Stable in steel containers when pure
Water Solubility	0.064 g/L water at ambient temperature
Hydrolysis Products	Diphenylarsenious oxide (very poisonous if taken internally) and hydrogen chloride
Flammability/Combustibility	No information
Decomposition Temperature	250°C (0.15% per minute)
Thermal Decomposition Products	No information

F.3.2 Bromobenzyl Cyanide (CA)

Synonym: BBC

F.3.2.1 Summary

Bromobenzyl cyanide (CA) is an industrial chemical that can act as a lacrimator and is an eye, skin, and respiratory tract irritant. Data on the environmental fate of bromobenzyl cyanide are limited. Persistence is dependent on ambient weather conditions.

F.3.2.2 Chemical Identity

Bromobenzyl cyanide was one of the first chemicals to be used as a tear gas agent (lacrimator). It is not as effective as chloroacetophenone or o-chlorobenzylidine malononitrile and is now obsolete. Table F.3.2-1 presents the relevant chemical identity information for bromobenzyl cyanide.

F.3.2.3 Physical-Chemical Properties

Table F.3.2-2 presents a summary of physical and chemical properties for bromobenzyl cyanide.

F.3.2.4 Environmental Fate and Transport

Atmospheric Fate

CA is a yellowish solid with a very low vapor pressure (0.011 mm/Hg at 20°C) and a high boiling point suggesting evaporation to the atmosphere is not a significant fate process [31]. It is a thermally unstable compound and will degrade on warm to hot surfaces after deposition [31].

Aquatic Fate

Data on the aquatic fate of bromobenzyl cyanide are limited. Bromobenzyl cyanide is slightly soluble in water and its rate of hydrolysis is extremely slow [31]. Therefore, rapid degradation of bromobenzyl cyanide in aquatic systems is not expected.

Terrestrial Fate

Data on the terrestrial fate of bromobenzyl cyanide are limited. Bromobenzyl cyanide is slightly soluble in water and its rate of hydrolysis is slow. Therefore, depending on soil moisture content, the rate of degradation in soil may be slow.

Table F.3.2-1. Chemical Identification Information—Bromobenzyl Cyanide

CAS Registry No.	16532-79-9
Type	Industrial chemical
Molecular Formula	C_8H_6BrN
Molecular Weight	196
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.2-2. Physical-Chemical Properties—Bromobenzyl Cyanide

Physical Form/Color	Yellow to white crystals when pure, otherwise oily brown liquid
Odor	Soured fruit, but not unpleasant
Relative Vapor Density (to air)	6.7
Vapor Pressure	0.011 mm Hg at 20°C
Boiling Point	242°C
Freezing Point	25.5°C when pure; 18.5°C, plant purity
Flash Point	None; decomposes but does not bum
Stability	Fairly stable in glass, lead-lined, or enamel-lined containers
Water Solubility	Slightly soluble to insoluble in water
Hydrolysis Products	None under ambient conditions.
Flammability/Combustibility	Not available
Decomposition Temperature	Slowly at 60°C; completely at 242°C
Thermal Decomposition Products	Hydrobromic acid and dicyanostilbene

F.3.3 Chloroacetophenone (CN), Chloroacetophenone in Benzene and Carbon Tetrachloride (CNB), and Chloroacetophenone and Chloropicrin in Chloroform (CNS)

Synonyms: 2-chloroacetophenone, mace

F.3.3.1 Summary

Chloroacetophenone (CN) and chloroacetophenone mixtures (CNB and CNS) are industrial chemicals that can act as lacrimators. These compounds cause irritation to the eyes and upper respiratory tract. CNS may also act as a vomiting and choking agent. In general, chloroacetophenone compounds are not expected to be persistent in the environment.

F.3.3.2 Chemical Identity

Chloroacetophenone and chloroacetophenone mixtures can act as tear producing agents (lacrimators). In addition, chloroacetophenone and chloropicrin in chloroform is also considered to be a vomiting and choking agent due to its chloropicrin component. Chloroacetophenone in benzene and carbon tetrachloride is comprised of 10 percent chloroacetophenone, 45 percent carbon tetrachloride, and 45 percent benzene. Chloroacetophenone and chloropicrin in chloroform is comprised of 23 percent chloroacetophenone, 38.4 percent chloropicrin, and 38.4 percent chloroform. Tables F.3.3-1 through F.3.3-3 present the relevant chemical identity information for chloroacetophenone and chloroacetophenone mixtures.

F.3.3.3 Physical-Chemical Properties

Table F.3.3-4 presents a summary of physical and chemical properties.

F.3.3.4 Environmental Fate and Transport

CN, CNB, and CNS are solutions of chloroacetophenone and chloropicrin in common organic solvents. When these solutions are released into the environment the organic solvent dissapers mostly by volatilization leaving chloroacetophenone and chloropicrin behind. The discussion below address the fate of the residual chloroacetophenone. Chloropicrin is discussed in Section F.3.6. Due to limited environmental fate and transport data, the following subsections are based on available information for chloroacetophenone.

Atmospheric Fate

Because chloroacetophenone is disseminated as an aerosol, it is not expected to be persistent. However, if released to the atmosphere, chloroacetophenone is expected to undergo slow atmospheric removal by a gas-phase reaction with photochemically produced hydroxyl radicals [29]. An estimated half-life for this process is 9.2 days. Chloroacetophenone may also reenter the atmosphere very slowly via volatilization from soil and water. Direct photolysis is not an important degradation pathway.

Aquatic Fate

Chloroacetophenone may volatilize slowly to the atmosphere from water [31]. The estimated half-lives for volatilization from a model river and pond are 13.3 and 159 days. It does not hydrolyze in water [31]. It hydrolyzes under alkaline conditions. But, the rate of alkaline hydrolysis is too slow at ambient temperatures [31]. In nitrate rich soils hydroxyl

radicals are formed from photolysis of nitrate with groundwater. Chloroacetophenone may be removed by reaction with hydroxyl radicals. No rate data is available for this reaction.

Terrestrial Fate

Chloroacetophenone is expected to be immobile in soil because of its insolubility in groundwater. Because of its insolubility in water it may partition into organic material in soil and degrade there more rapidly than in groundwater. Insufficient data are available to estimate the significance of soil degradation processes.

Table F.3.3-1. Chemical Identification Information—Chloroacetophenone

CAS Registry No.	532-27-4
Type	Industrial chemical
Molecular Formula	$C_6H_5COCH_2Cl$
Molecular Weight	154.6
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.3-2. Chemical Identification Information—Chloroacetophenone in Benzene and Carbon Tetrachloride

CAS Registry No.	No information
Synonyms	Chloroacetophenone in carbon tetrachloride and benzene
Type	Industrial chemical
Molecular Formula	CN (10%), CCl_4 (45%), C_6H_6 (45%)
Molecular Weight	119.7
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.3-3. Chemical Identification Information—Chloroacetophenone and Chloropicrin in Chloroform

CAS Registry No.	No information
Synonyms	Chloroacetophenone and chloropicrin in chloroform
Type	Industrial chemical
Molecular Formula	CN (23%), $C(NO_2)Cl_3$ (38.4%), $CHCl_3$ (38.4%)
Molecular Weight	141.8
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.3-4. Physical-Chemical Properties—Chloroacetophenone

Physical Form/Color	Colorless to gray crystalline solid
Relative Vapor Density (to air)	5.2
Vapor Pressure	0.0041 to 0.012 mm Hg at 20°C
Boiling Point	244 to 248°C
Freezing Point	54 to 59°C
Flash Point	118°C
Stability	Stable; heat contributes to instability
Water Solubility	0.11 g/L (estimated)
Hydrolysis Products	Very slowly to hydrogen chloride, alpha-hydroxyacetophenone
Flammability/Combustibility	May burn, but does not readily ignite; container may explode violently in heat of fire
Decomposition Temperature	Stable up to boiling point
Thermal Decomposition Products	Hydrogen chloride fumes, carbon monoxide, and carbon dioxide

F.3.4 Chlorobenzene

Synonyms: monochlorobenzene, benzene chloride, MCB, chlorobenzol, phenyl chloride

F.3.4.1 Summary

Chlorobenzene is an industrial chemical that can act as a choking agent. Its persistence in the environment is largely governed by evaporation, although some biodegradation may occur.

F.3.4.2 Chemical Identity

Chlorobenzene is militarily categorized as a choking agent; however, it is also a common industrial solvent.

Table F.3.4-1 presents the relevant chemical identity information for chlorobenzene.

F.3.4.3 Physical-Chemical Properties

Table F.3.4-2 presents a summary of available physical and chemical properties.

F.3.4.4 Environmental Fate and Transport

In general, evaporation is the primary process governing the fate of chlorobenzene in the environment [118]. The rate of biodegradation in the environment is slow, but may be significant in some situations. The following subsections discuss the atmospheric, terrestrial, and aquatic fate and transport properties of chlorobenzene.

Atmospheric Fate

Following release to the air, the dominant removal process for chlorobenzene in the atmosphere is expected to be by reaction with hydroxyl radicals to form chlorophenols with estimated residence times of 13-116 days [119,120,123,129]. The reaction is faster in air polluted with nitric oxide and produces chloronitrobenzene and chloronitrophenols. Direct photolysis also occurs to a limited extent and produces monochlorobiphenyl [130].

Aquatic Fate

The primary removal process of chlorobenzene from water is evaporation [118,123,129,130]. The rate of evaporation depends on wind speed and water movement. The half-life for evaporation from water is approximately 1-12 hours in a river [129,130] and about 75 days in sediments [130]. It may react with photochemically generated hydroxyl radicals and form chlorophenol in surface waters. Residence times of 1 day in rivers to over 100 days in groundwater have been reported [123]. However, this pathway may be very slow. Chlorobenzene is not very soluble in water and does not hydrolyze.

Scores of studies on biodegradation have been published. Biodegradation of chlorobenzene occurs under aerobic conditions and the product is 4-chlorophenol [124]. Mineralization of chlorobenzene to carbon dioxide and chloride has also been reported [125,126]. Biodegradation occurs during warmer seasons and will proceed more rapidly in fresh water than in salt water. One study reported half-life of 46 days at 25°C under near

natural conditions [122]. A moderate amount of adsorption onto organic sediments would also be expected, which would extend the persistency of chlorobenzene in aquatic systems.

Terrestrial Fate

Since chlorobenzene is fairly volatile [11.8 mm Hg at 25°C], much of it will evaporate to the atmosphere from terrestrial surfaces with a half-life of about 7 hours to 13 days [129,130]. It is relatively mobile in sandy soil and aquifer material, and biodegrades very slowly in these soils. As a result, it can be expected to leach into groundwater. Chlorobenzene has a significantly high octanol-water partition coefficient (Log K_{ow} = 2.84) and has the potential to adsorb onto soil high in organic content and, if retained long enough, will biodegrade to 2 and 4-chlorophenol and it also mineralizes under certain conditions [130,123]. In general, degradation in soil is a slow process.

Table F.3.4-1. Chemical Identification Information—Chlorobenzene

CAS Registry No.	108-90-7
Type	Industrial chemical
Molecular Formula	C_6H_5Cl
Molecular Weight	112.6
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.4-2. Physical-Chemical Properties—Chlorobenzene

Physical Form/Color	Colorless liquid
Odor	Faint almond-like
Relative Vapor Density (to air)	3.9
Vapor Pressure	11.8 mm Hg at 20°C
Boiling Point	132°C
Henry's Law Constant, K_H	4.538×10^{-3} atm-m^3/mol
Log K_{ow}	2.84
Freezing Point	-45.6 to -55°C
Density or Specific Gravity	1.107 g/mL
Flash Point	28°C
Stability	Stable at ambient temperatures in standard fire-resistant flammable liquid storage area; separate from oxidizing materials.
Water Solubility	Slight (0.448 g/L)
Hydrolysis Products	Does not hydrolyze.
Flammability/Combustibility	Flammable, contact with strong oxidizers may cause fires and explosions; vapors subject to flash back.
Decomposition Temperature	No information
Thermal Decomposition Products	Phosgene, hydrogen chloride, carbon monoxide, and carbon dioxide

F.3.5 Chloroform

Synonym: Trichloromethane

F.3.5.1 Summary

Chloroform is an industrial chemical that can act as a lacrimator. The primary environmental fate process for chloroform is evaporation.

F.3.5.2 Chemical Identity

Chloroform is a tear agent (lacrimator). It is a commonly used solvent, extractant, and chemical intermediate. Table F.3.5-1 presents the relevant chemical identity information for chloroform.

F.3.5.3 Physical-Chemical Properties

Table F.3.5-2 presents a summary of physical and chemical properties of chloroform.

F.3.5.4 Environmental Fate and Transport

Atmospheric Fate

When released into the atmosphere chloroform will remain in the vapor phase as indicated by its high vapor pressure. It is not expected to deposit back to earth. Once in the atmosphere chloroform will travel considerable distances before degradation occurs. Its lifetime in the troposphere has been estimated to be 2 to 3 months. Chloroform released to the atmosphere will degrade by reaction with hydroxyl radicals with a half-life of 80 days based on a 12-hour sunlit day. Direct photolysis is not an important pathway [93]

Aquatic Fate

The major fate process for chloroform in surface waters is volatilization as indicated by its Henry's Law constant and solubility in water [91,94]. Volatilization is faster in turbid waters [92]. The measured half-life for evaporation ranges from 36 hours in rivers to about 10 days in lakes [93]. Little chloroform is adsorbed to sediment or organic matter in soil. Hydrolysis in water is too slow to be of any significance [93]. Direct photodegradation and indirect reaction with hydroxyl radicals do not appear to be important fate process in aquatic systems [95].

Terrestrial Fate

The primary terrestrial fate of chloroform is evaporation, due to its high vapor pressure [160 mm Hg at 20°C]. It is poorly adsorbed to soil, especially soil low in organic content and can leach into groundwater. There are numerous publications on biodegradation of chloroform. It has been shown that in river sediments chloroform is anaerobically mineralized to carbon dioxide with a half-life of 2-37 days [96]. Certain types of methanogenic bacteria, such as *Methanosarcina,* are capable of dechlorinating chloroform in a stepwise fashion all the way to methane which volatilizes [97,98,99]. These anaerobic degradations are due to reduction reactions occurring in bacterial cells that contain heme (Fe^{2+}) proteins [98].

Table F.3.5-1. Chemical Identification Information—Chloroform

CAS Registry No.	67-66-3
Class of Agent	Industrial solvent
Molecular Formula	$CHCl_3$
Molecular Weight	119.4
Other Hazardous Chemicals in Mixture	N/A

Table F.3.5-2. Physical-Chemical Properties—Chloroform

Physical Form/Color	Colorless liquid
Odor	Sweet, pleasant, etheric
Relative Vapor Density (to air)	4.1
Vapor Pressure	160 mm Hg at 20°C
Boiling Point	61°C
Henry's Law Constant, K_H	4.053×10^{-3} atm-m^3/mol
Freezing Point	-64°C
Density or Specific Gravity	1.492 g/mL
Flash Point	Will not ignite
Stability	Stable in ordinary pressure up to boiling point; can be explosive when confined with water
Water Solubility	7.95 g/L at 25°C
Hydrolysis Products	None. Reduced to methane by bacteria.
Flammability/Combustibility	Not combustible but will burn with prolonged exposure to flame or high temperatures
Decomposition Temperature	225°C
Thermal Decomposition Products	Toxic phosgene and oxides of carbon and hydrogen chloride; accelerated by iron and water at high temperatures

F.3.6 Chloropicrin (PS)

Synonyms: nitrochloromethane, trichloronitromethane, nitrochloroform

F.3.6.1 Summary

Chloropicrin (PS) is an industrial chemical that can act as a lacrimator and vomiting agent. In the environment, chloropicrin is relatively non-persistent and will undergo multiple degradation processes.

F.3.6.2 Chemical Identity

Table F.3.6-1 presents the relevant chemical identity information for chloropicrin.

F.3.6.3 Physical-Chemical Properties

Table F.3.6-2 presents a summary of physical and chemical properties of chloropicrin.

F.3.6.4 Environmental Fate and Transport

Atmospheric Fate

Chloropicrin is a very volatile compound and can remain air as a vapor even at low temperatures although toxic air concentrations will not develop under winter conditions [31]. If released to the atmosphere, chloropicrin will photolyze (half-life of 20 days) producing chlorine and oxides of nitrogen [31]. Chloropicrin also slowly reacts with hydroxyl radicals with a predicted half-life of 123 days. Photochemical experiments have shown that chloropicrin release chlorine atoms photolytically and the chlorine atoms react with a number of organic compounds in the atmosphere [102]. Chloropicrin in the atmosphere significantly increases NO oxidation and ozone formation. Since it is relatively soluble in water, chloropicrin may also be washed out to ground surfaces by rain.

Aquatic Fate

Chloropicrin is expected to readily volatilize from water. It is stable in water [103]. It hydrolyzes extremely slowly [104]. Even at 100°C only 1.3% of this compound hydrolyzes in one hour [104]. Its half-lives in a model river and model lake are 4.3 hours and 5.2 days, respectively. Chloropicrin will also photodegrade from the water surface. Chloropicrin is not expected to adsorb to sediment.

Terrestrial Fate

Chloropicrin applied to soil will rapidly volatilize and leach. It is also expected to photolyze on soil surfaces [31].

Table F.3.6-1. Chemical Identification Information—Chloropicrin

CAS Registry No.	76-06-2
Type	Industrial chemical
Molecular Formula	CCl_3NO_2
Molecular Weight	164.4
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.6-2. Physical-Chemical Properties—Chloropicrin

Physical Form/Color	Colorless to faint yellow oily liquid
Odor	Sharp, penetrating odor
Relative Vapor Density (to air)	5.7
Vapor Pressure	20 mm Hg at 20°C
Boiling Point	112°C at 760 mm Hg
Freezing Point	-69°C
Flash Point	Not combustible, but with strong initiation, heated material under confinement will detonate
Stability	Unstable in high temperatures or after severe shock; particularly containers of greater than 30-gallon capacity
Water Solubility	1.8 g/L water at 20°C
Hydrolysis Products	HCl and nitrogen oxides. Extremely slow reaction.
Flammability/Combustibility	See "Flash Point"
Decomposition Temperature	Above 400°C
Thermal Decomposition Products	Oxide gases of nitrogen, phosgene, nitrosyl chloride, chlorine, and carbon monoxide

F.3.7 Cyanogen Chloride (CK)

Synonyms: chlorocyan, chlorine cyanide, chlorocyanogen

F.3.7.1 Summary

Cyanogen chloride (CK) is an industrial chemical that is toxic following inhalation, ingestion, and dermal absorption. Limited environmental fate and transport data are available for cyanogen chloride. However, because of its high volatility and ability to react with water, cyanogen chloride is not expected to be persistent in the environment.

F.3.7.2 Chemical Identity

Cyanogen chloride is toxic in both the liquid and vapor phases. Table F.3.7-1 presents the relevant chemical identity information for cyanogen chloride.

F.3.7.3 Physical-Chemical Properties

Table F.3.7-2 presents a summary of physical and chemical properties.

F.3.7.4 Environmental Fate and Transport

Cyanogen chloride is very volatile. No data on its atmospheric fate is available. CK has significant solubility in water and hydrolyzes rapidly. Thus, it will not be persistent. Hydrolysis occurs under alkaline conditions to form cyanic acid and hydrochloric acid. CK has a half-life of 1 minute at 45°C and about 10 hours at 5°C [100]. The same products are formed under neutral and acidic conditions albeit more slowly [20]. According to the American Public Health Association (APHA) CK may persist in water for 24 hours at a pH of 9 if no chlorine is present [101]. No data on its fate in soil is available. It is reasonable to assume that CK will partition from soil to groundwater and under go hydrolysis.

Table F.3.7-1. Chemical Identification Information—Cyanogen Chloride

CAS Registry No.	506-77-4
Type	Industrial chemical
Molecular Formula	CNCl
Molecular Weight	61.48
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.7-2. Physical-Chemical Properties—Cyanogen Chloride

Physical Form/Color	Colorless gas or liquid
Odor	Irritating and lacrimatory properties are so great that odor can go undetected; pungent and biting
Relative Vapor Density (to air)	2.1
Vapor Pressure	1,000 mm Hg at 25°C
Boiling Point	12.8 to 13.1°C
Freezing Point	-136°C
Flash Point	None
Stability	In presence of stabilizing agents, stable at 65°C for 30 days; tends to undergo condensation or violent polymerization in storage (may explode)
Water Solubility	69 g/L
Hydrolysis Products	Cyanic acid (HOCN) and hydrogen chloride (HCl)
Flammability/Combustibility	Impurities may promote polymerization, which may occur with explosive violence (catalyzed by high temperatures and moisture)
Decomposition Temperature	Above 100°C
Thermal Decomposition Products	Poisonous gas produced in heat of fire (chlorides, cyanide, and nitrous oxides)

F.3.8 GA Simulants

Synonym: diethyl malonate

F.3.8.1 Summary

Diethyl malonate is a component of a mixture of organic compounds used as GA simulants. No environmental fate data are available.

F.3.8.2 Chemical Identity

Diethyl malonate is the diethyl ester of malonic acid. It is widely used in the manufacture of pharmaceuticals, antioxidants, and dyes. Its chemical identification information is given in Table F-3.8.1.

F.3.8.3 Physical-Chemical Properties

Table F.3.8-2 presents a summary of physical and chemical properties of diethyl malonate.

F.3.8.4 Environmental Fate and Transport

No data on the environmental fate and transport of diethyl malonate were found. It has a low vapor pressure and a high boiling point. Any diethyl malonate released to the atmosphere is likely to deposit back to earth. It should not volatilize significantly from soils and water. It is sparingly soluble in water and thus may be leached from soils and transported. It may hydrolyze to the monoethyl ester of malonic acid and ethanol both of which are soluble in water and should not persist in soils and groundwater. The loss of the second ester group is very slow.

Table F.3.8-1. Chemical Identification Information—Diethyl Malonate (Component of GA Simulant)

CAS Registry No.	105-53-3
Synonyms	Diethyl malonate, diethyl ester, ethyl malonate
Type	Industrial chemical
Molecular Formula	$C_7H_{12}O_4$
Molecular Weight	No information
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.8-2. Physical-Chemical Properties—Diethyl Malonate (Component of GA Simulant)

Physical Form/Color	Colorless liquid
Odor	Sweet ester odor
Relative Vapor Density (to air)	5.5
Vapor Pressure	< 1 mm Hg
Boiling Point	198°C
Freezing Point	-50°C
Flash Point	75°C
Stability	No information
Water Solubility	28 g/L
Hydrolysis Products	Monoethyl ester of malonic acid and ethanol. Very slow.
Flammability/Combustibility	Combustible
Decomposition Temperature	No information
Thermal Decomposition Products	Toxic fumes of carbon monoxide and carbon dioxide

F.3.9 Hydrogen Cyanide (AC)

Synonym: hydrocyanic acid

F.3.9.1 Summary

Hydrogen cyanide (AC) is an industrial chemical, which is highly toxic following inhalation, ingestion, and dermal absorption. When released, it is more persistent in the air and soil than in aquatic systems. Volatilization is an important environmental fate process for hydrogen cyanide; degradation and hydrolysis are expected to be rapid.

F.3.9.2 Chemical Identity

Hydrogen cyanide is toxic as both a gas and a liquid. Table F.3.9-1 presents the relevant chemical identity information for hydrogen cyanide.

F.3.9.3 Physical-Chemical Properties

Table F.3.9-2 presents a summary of physical and chemical properties of hydrogen cyanide.

F.3.9.4 Environmental Fate and Transport

Atmospheric Fate

Hydrogen cyanide released to the atmosphere is expected to exist entirely as a gas. Reaction with photochemically produced hydroxyl radicals is slow (half-life of 334 days). Hydrogen cyanide is to be resistant to direct photolysis. The relative slow rate of degradation suggests that it has the potential to be transported over long distances before being removed from the air by physical or chemical processes. Since hydrogen cyanide is miscible with water, wet deposition is an important atmospheric fate process.

Aquatic Fate

Hydrogen cyanide is extremely soluble in water and the solubility increases as the pH increases due to acid-base reaction. It hydrolyzes, in several steps, to form formic acid and ammonia [20,31]. Products of hydrolysis are soluble in water.

Terrestrial Fate

Based on the fate of cyanides in water, it is predicted that the fate of hydrogen cyanide in soil would be pH-dependent. It will not volatilize out of alkaline soils because of formation of soluble cyanide salts. In subsurface soils, cyanide present in low concentrations will likely biodegrade. In situations where cyanide levels are toxic to microorganisms, hydrogen cyanide may escape biodegradation and leach into groundwater.

Table F.3.9-1. Chemical Identification Information—Hydrogen Cyanide

CAS Registry No.	74-90-8
Type	Industrial chemical
Molecular Formula	HCN
Molecular Weight	27.0
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.9-2. Physical-Chemical Properties—Hydrogen Cyanide

Physical Form/Color	Colorless gas or liquid
Odor	Similar to bitter almonds
Relative Vapor Density (to air)	0.93 at 18°C; 0.99 at 20°C
Vapor Pressure	742 mm Hg at 25°C
Boiling Point	25.7°C
Freezing Point	-13.3°C
Flash Point	- 18°C (closed cup)
Stability	Unstable except when very pure; forms explosive polymer on long standing—can be stabilized by addition of small amounts of phosphoric acid or sulfur dioxide
Water Solubility	Miscible
Hydrolysis products	Ammonia and formaldehyde
Flammability/Combustibility	May be ignited by fire, heated materials, and sparks
Decomposition Temperature	Above 65.5°C
Thermal Decomposition Products	No information

F.3.10 Nitrobenzene

Synonyms: Nitrobenzol, Mirbane oil

F.3.10.1 Summary

Nitrobenzene is a commonly used solvent that exhibits toxic effects following inhalation, ingestion, and dermal absorption. Data describing the rate of environmental fate processes are limited.

F.3.10.2 Chemical Identity

Nitrobenzene is an oily yellow liquid with an almond-like odor. It may be pale yellow-brown in appearance. It dissolves only slightly in water. Nitrobenzene is produced in large quantities for industrial use. Approximately 98% of the nitrobenzene produced in the United States is used to manufacture aniline. Nitrobenzene is also used to produce lubricating oils such as those used in motors and machinery. A very small amount of nitrobenzene is used in the manufacture of dyes, drugs, pesticides, and synthetic rubber.

Table F.3.10-1 presents the relevant chemical identity information for nitrobenzene.

F.3.10.3 Physical-Chemical Properties

Table F.3.10-2 presents a summary of available physical and chemical properties.

F.3.10.4 Environmental Fate and Transport

Atmospheric Fate

Nitrobenzene will degrade in the atmosphere primarily by photolysis to give ortho- and para-nitrophenols and nitrosobenzene. Thirty-eight percent degradation was observed in 5 hours in laboratory tests [130,131]. The rate of reaction with photochemically produced hydroxyl radicals and ozone is relatively slow with half-life ranging from 90 days to 2 years. [129-131]. Modeling studies and field experiments suggest that wet deposition will have little effect on the loss of nitrobenzene from the atmosphere [131].

Aquatic Fate

Nitrobenzene is slightly soluble in water. It is not expected to volatilize significantly from water [131]. It is denser than water and tends to sink in water and soils [110]. It does not hydrolyze in water. It has been shown that nitrobenzene degrades in water by reaction with photochemically generated hydroxyl radicals in surface waters [109]. In the presence of iron or low-valent iron compounds such as iron porphyrins nitrobenzene degrades to aniline via nitrosobenzene [111, 112]. These reactions may also occur in microorganisms containing heme proteins [98].

There are scores of papers in the biochemical literature on the biodegradation of nitrobenzene. The process is an anaerobic reduction of nitrobenzene to aniline with reported experimental half-life values being 1 to 38 days. [115, 116]. For example, bacteria *Pseudomonas pseudoalcaligenes*, have been shown to consume nitrobenzene as source of carbon, nitrogen, and energy and in the process convert nitrobenzene to aniline and hydroxy

anilines [114]. The overall half-life of nitrobenzene in aquatic environments is estimated at 7 hours by the USEPA [132].

Terrestrial Fate

Nitrobenzene is moderately adsorbed to soil and is expected to undergo leaching and biodegradation within a few weeks of release to the terrestrial environment [110,117,130].

Table F.3.10-1. Chemical Identification Information—Nitrobenzene

CAS Registry No.	98-95-3
Type	Industrial solvent
Molecular Formula	$C_6H_5NO_2$
Molecular Weight	123.1
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.10-2. Physical-Chemical Properties—Nitrobenzene

Physical Form/Color	Yellow viscous liquid
Odor	Almond; shoe polish
Relative Vapor Density (to air)	4.3
Vapor Pressure	<1 mm Hg at 20°C
Boiling Point	211°C
Freezing Point	-5.6°C
Density or Specific Gravity	1.2 g/mL
Flash Point	87°C
Stability	Stable; store in cool, dry, well ventilated flammable liquid storage area; avoid heat, flame, other sources of ignition, freezing, and light
Water Solubility	Slight (1 to 10 g/L)
Hydrolysis Products	Does not occur.
Flammability/Combustibility	Closed containers exposed to heat may explode; contact with strong oxidizers may cause fires; vapors subject to flash back.
Decomposition Temperature	No information
Thermal Decomposition Products	Oxides of nitrogen, carbon monoxide, and carbon dioxide

F.3.11 Phosgene (CG) and Diphosgene (DP)

Synonyms: carbonyl chloride, carbon dichloride oxide, carbon oxychloride,trichloromethyl chloroformate, perchloromethyl formate

F.3.11.1 Summary

Phosgene (CG) and diphosgene (DP) are industrial chemicals that can act as choking agents and may be lethal when inhaled. Processes affecting the environmental fate of phosgene include hydrolysis, volatilization, and photolysis. Diphosgene is very persistent in the atmosphere. Little environmental fate information is available for diphosgene.

F.3.11.2 Chemical Identity

Phosgene and diphosgene are choking agents and respiratory irritants. In the absence of moisture phosgene is stable. Under intense heat phosgene dissociates to chlorine and carbon monoxide. When heated diphosgene will decompose yielding two molecules of phosgene and the decomposition is complete at 350°C [31]. Each agent produces hydrogen chloride following hydrolysis. Tables F.3.11-1 and F.3.11-2 present the relevant chemical identity information for phosgene and diphosgene, respectively.

F.3.11.3 Physical-Chemical Properties

Phosgene is a colorless gas. Diphosgene is a colorless oily liquid. Diphosgene is less volatile than phosgene. Tables F.3.11-3 and F.3.11-4 present a summary of physical and chemical properties.

F.3.11.4 Environmental Fate and Transport

Environmental fate and transport data for diphosgene are limited [31].

Atmospheric Fate

Phosgene is a colorless gas under ambient conditions. It condenses to a colorless liquid below 8°C. Even at low temperatures phosgene has sufficient vapor pressure to generate toxic concentrations in air. It persists in air for about 3 hours even at –20°C. In warmer climates it is not persistent in air. Moisture in air does not hydrolyze phosgene. Under very humid conditions hydrolysis takes place producing hydrogen chloride fumes. Phosgene can rise to the troposphere although photolysis is not an important fate. Above the cloud layers phosgene can persist for longer than 10 years [99]. However, phosgene released at the surface will survive only a few days through its passage through the clouds [99]

There is no data on the atmospheric fate of diphosgene. It has much lower volatility than phosgene. Its persistence in air is longer during winters than during summers. Under certain conditions, it may dissociate to phosgene [31].

Aquatic Fate

Phosgene released in water is extremely rapidly lost by hydrolysis to hydrochloric acid and carbon dioxide. 10 g of phosgene is decomposed by bulk water completely in 20 seconds [31].

Diphosgene hydrolyzes much more slowly than phosgene. Alkaline conditions and higher temperatures accelerate the degradation. It decomposes to hydrochloric acid and carbon dioxide.

Terrestrial Fate

The fate of phosgene released on land is unknown. While phosgene adsorbs strongly to relatively dry soils, it is likely to volatilize and hydrolyze when released to wet soils. Diphosgene behaves similarly. It is known that iron oxides which are found in soils and clay accelerate the decomposition of diphosgene to carbondioxide and hydrochloric acid [31].

Table F.3.11-1. Chemical Identification Information—Phosgene

CAS Registry No.	75-44-5
Type	Industrial chemical
Molecular Formula	$COCl_2$
Molecular Weight	98.9
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.11-2. Chemical Identification Information—Diphosgene

CAS Registry No.	503-38-8
Type	Industrial chemical
Molecular Formula	$C_2Cl_4O_2$
Molecular Weight	197.9
Other Hazardous Chemicals in Mixture	Not applicable

Table F-3.11-3. Physical-Chemical Properties—Phosgene

Physical Form/Color	Colorless gas
Odor	New-mown hay or grass; green corn; decaying fruit
Relative Vapor Density (to air)	3.4
Vapor Pressure	1,173 to 1,180 mm Hg at 20°C
Boiling Point	7.6°C
Henry's Law Constant, K_H	
Log K_{ow}	
Freezing Point	-128°C
Density or Specific Gravity	1.644 g/mL
Flash Point	None
Stability	Stable in steel containers if dry
Water Solubility	Slightly soluble; decomposes immediately
Hydrolysis Products	Hydrogen chloride and carbon dioxide
Flammability/Combustibility	May burn but does not readily ignite; not combustible;cylinder may explode in heat of fire
Decomposition Temperature	800°C
Thermal Decomposition Products	Toxic fumes (Chlorine and carbon monoxide)

Table F-3.11-4. Physical-Chemical Properties—Diphosgene

Physical Form/Color	Colorless liquid
Odor	New-mown hay or grass; green corn
Relative Vapor Density (to air)	6.8
Vapor Pressure	4.2 to 10 mm Hg at 20°C
Boiling Point	127 to 128°C
Freezing Point	-57°C
Flash Point	None
Stability	Unstable because of conversion to phosgene
Water Solubility	Limited in water
Hydrolysis Products	Hydrogen chloride and carbon dioxide
Flammability/Combustibility	Noncombustible
Decomposition Temperature	300 to 350°C
Thermal Decomposition Products	Phosgene, chlorine, and carbon monoxide.

F.3.12 3-Quinuclidinyl Benzilate (BZ)

Synonym: QB

F.3.12.1 Summary

3-Quinuclidinyl benzilate (BZ) is an industrial chemical that can act as an incapacitating agent and interfere with the function of the central nervous system. Data on the environmental fate of BZ are limited; however, based on its physical and chemical properties, BZ may be relatively persistent.

F.3.12.2 Chemical Identity

BZ is a potent psychoactive compound that can act as an incapacitating agent. Table F.3.12-1 presents the available chemical identity information for BZ.

F.3.12.3 Physical-Chemical Properties

Table F.3.12-2 presents a summary of available physical and chemical properties.

F.3.12.4 Environmental Fate and Transport

Environmental fate and transport data for BZ are limited. Data suggest that it is resistant to atmospheric degradation. It has a very low solubility in water [46,105]. It hydrolyzes to quinuclidinol and benzilic acid [46,105]. The tertiary amine group in this compound can be protonated under acidic conditions and the protonated BZ is very soluble in water [106]. The hydrolysis rate is at a minimum at pH 4 and increases rapidly as the pH is raised or lowered. Half-life at 25°C, pH 7 is 3 to 4 weeks; 400 minutes at pH 9.8; and, 1.8 minutes at pH 13. Thus, BZ persistence in water and soil is a function of pH.

Table F.3.12-1. Chemical Identification Information—BZ

CAS Registry No.	6581-06-2
Type	Industrial chemical
Molecular Formula	$C_{21}H_{23}NO_3$
Molecular Weight	337.4
Other Hazardous Chemicals in Mixture	Not applicable

Table F.3.12-2. Physical-Chemical Properties—BZ

Physical Form/Color	Beige to white crystalline solid
Odor	Odorless
Relative Vapor Density (to air)	11.6
Vapor Pressure	Negligible; approximately 0.5 mm Hg at 70°C
Boiling Point	320 to 412°C
Freezing Point	167.5°C
Flash Point	246°C
Stability	Resistant to atmospheric degradation; stable in storage; thermally stable above melting point
Water Solubility	Negligible
Hydrolysis Products	Quinuclidinol and benzilic acid
Flammability/Combustibility	Combustible solid and can form explosive mixtures in air. Explosive limits: 0.88 to 2.5 g/ft^3
Decomposition Temperature	170 to 200°C
Thermal Decomposition Products	Carbon monoxide, carbon dioxide, benzophenone, benzhydrol

F.3.13 Triphosgene

Synonym: bis(trichloromethyl)carbonate

F.3.13.1 Summary

Triphosgene is an industrial chemical that can act as a strong lacrimator. Environmental fate and transport data are limited; however, triphosgene may decompose in the presence of moisture or water.

F.3.13.2 Chemical Identity

Triphosgene is an agent simulant and can act as a strong lachrymator. Table F.3.13-1 presents the relevant chemical identity information for triphosgene.

F.3.13.3 Physical-Chemical Properties

Table F.3.13-2 presents a summary of physical and chemical properties of triphosgene.

F.3.13.4 Environmental Fate and Transport

Limited fate and transport data were available for triphosgene. It decomposes to phosgene and diphosgene at elevated temperatures. It is far less volatile than phosgene or diphosgene. Triphosgene decomposes to carbon dioxide and hydrochloric acid on exposure to water [31].

Table F.3.13-1. Chemical Identification Information—Triphosgene

CAS Registry No.	32315-10-9
Type	Industrial chemical
Molecular Formula	$C_3Cl_6O_3$
Molecular Weight	296.8
Other Hazardous Chemicals in Mixture	Phosgene

Table F.3.13-2. Physical-Chemical Properties—Triphosgene

Physical Form/Color	White to off-white crystals
Odor	No information
Relative Vapor Density (to air)	No information
Vapor Pressure	758 mm Hg at 206°C
Boiling Point	203 to 206°C
Freezing Point	77 to 80°C
Density or Specific Gravity	1.6 g/mL
Flash Point	No information
Stability	May decompose on exposure to moist air or water
Water Solubility	Practically insoluble
Hydrolysis Products	carbon dioxide and hydrochloric acid.
Flammability/Combustibility	No information
Decomposition Temperature	No information
Thermal Decomposition Products	Phosgene, diphosgene, chlorine, carbon monoxide and carbon dioxide,

F.4 Treatment Chemicals

Chemicals would be added to chemical warfare agents and, sometimes, to industrial chemical phosgene as treatment reagents to neutralize the lethal properties of the agents or phosgene. These treatment reagents are discussed in this section.

F.4.1 Monoethanolamine (MEA)

Synonyms: 2-aminoethanol, ethanolamine

F.4.1.1 Summary

Monoethanolamine (MEA) will be used in the transportable chemical treatment systems as a treatment reagent. This is by far the largest component by volume in the wastes generated by the MMD-1 technology. Limited environmental fate data show that MEA dissolves in water, is transported rapidly, and also biodegrades rapidly. Thus, it is not likely to be persistent in the environment as MEA is miscible with water and is transported.

F.4.1.2 Chemical Identity

Table F.4.1-1 presents the relevant chemical identity information for MEA.

F.4.1.3 Physical-Chemical Properties

Table F.4.1-2 presents a summary of physical and chemical properties.

F.4.1.4 Environmental Fate and Transport

Atmospheric Fate

MEA has a low vapor pressure and a high boiling point. When released into atmosphere it will associate strongly with moisture and deposit to earth. Amines and alkanolamines are very good radical scavengers [51] and MEA in air will degrade by reaction with photochemically generated hydroxyl radicals in air with a half-life of about 11 hours [79,80]. Because of its short life in the atnosphere MEA will not strongly affect air quality.

Aquatic Fate

MEA is completely miscible with water and form basic solutions. In acidic waters MEA forms quarternary ammonium salts and remains dissolved. Volatilization from water is not significant especially if water is acidic. MEA is chemically stable in water.

Terrestrial Fate

MEA has the potential to sorb to soils. However, because of its infinite solubility in water any adsorbed MEA will be leached and transported. MEA will not be persistent in soils or soil organic materials.

Alkanolamines are widely used in the chemical industry and consequently there is considerable literature on its biodegradation. It has been shown that the bacteria *Escherichia coli*, cleave MEA to ammonium ion and acetaldehyde, assimilate ammonium as a nitrogen source and oxidizes acetaldehyde to acetic acid. [79,81]. Under aerobic conditions MEA is mineralized to ammonium and CO_2 in 28 days [82] In another study, it was shown that the bacteria *Mycobacterium aurum MO1*, mineralized MEA in 4 to 8 hours [83]

Table F.4.1-1. Chemical Identification Information—Monoethanolamine

CAS Registry No.	141-43-5
Synonyms	2-aminoethanol, ethanolamine,
Type	Treatment chemical
Molecular Formula	$HOCH_2CH_2NH_2$
Molecular Weight	61.1
Other Hazardous Chemicals in Mixture	Not applicable

Table F.4.1-2. Physical-Chemical Properties—Monoethanolamine

Physical Form/Color	Colorless liquid
Odor	Like ammonia
Relative Vapor Density (to air)	2.1
Vapor Pressure	0.2 mm Hg
Boiling Point	171°C
Density or Specific Gravity	1.015 g/mL
Freezing Point	No information
Flash Point	85°C (closed cup)
Stability	Stable
Water Solubility	Completely soluble
Hydrolysis Products	Does not hydrolyze
Flammability/Combustibility	Vapors may flow to distant ignition sources and flash back; closed containers exposed to heat may explode; contact with strong oxidizers may cause fire
Decomposition Temperature	No information
Thermal Decomposition Products	Ammonia, nitrogen oxides, carbon monoxide, and carbon dioxide

F.4.2 1,3-Dichloro-5,5-Dimethylhydantoin (DCDMH)

Synonyms: none

F.4.2.1 Summary

1,3-Dichloro-5,5-dimethylhydantoin (DCDMH) will be used in the RRStransportable chemical treatment systems as a treatment reagent. DCDMH is slightly soluble in water and is not expected to be very persistent in the environment.

F.4.2.2 Chemical Identity

Table F.4.2-1 presents the relevant chemical identity information for DCDMH.

F.4.2.3 Physical-Chemical Properties

Table F.4.2-2 presents a summary of physical and chemical properties.

F.4.2.4 Environmental Fate and Transport

Limited environmental data are available for DCDMH. DCDMH is used as a source of chlorine for use as a disinfectant and a microbicide. DCDMH is an N-chloramine that contains labile N-Cl bonds. N-chloramines react with water to release hypochlorite ions and form N-H bonds [86]. In wet soil and water DCDMH reacts with water to generate hypochlorite ion which is a strong oxidizing agent. Thus it is reasonable to assume that DCDMH is not very persistent in the moist environment. The other products of its reaction with water are monochlorodimethylhydantoin and dimethylhydantoin. These are urea-like nitrogen containing compounds. As the soil and water pH rises DCDMH is decomposed to $(CH3)_2CHNHCl$, chloride, and nitrogen [84]. No environmental information on these compounds is available. It is reasonable to assume they will biodegrade and mineralize very much like amines and ureas.

Table F.4.2-1. Chemical Identification Information—DCDMH

CAS Registry No.	118-52-5
Type	Treatment chemical
Molecular Formula	C5H6Cl2N2O2
Molecular Weight	197
Other Hazardous Chemicals in Mixture	Not applicable

Table F.4.2-2. Physical-Chemical Properties—DCDMH

Physical Form/Color	White solid
Odor	Chlorine-like
Relative Vapor Density (to air)	No information
Vapor Pressure	No information
Boiling Point	100°C
Freezing Point	No information
Flash Point	171°C; 191°C
Stability	Stable at normal temperatures and pressures; store in cool/dry place
Water Solubility	Slightly soluble
Hydrolysis Products	Chlorodimethylhydantoin, Dimethylhydantoin, Hypochlorite ions. Completely decomposes above pH 9.
Flammability/Combustibility	May explode in heat of fire
Decomposition Temperature	191 °C
Thermal Decomposition Products	Hydrogen chloride, nitrogen oxides, phosgene, carbon monoxide, carbon dioxide, and nitrogen

F.4.3 Sodium Hydroxide (NaOH)

Synonyms: caustic soda, sodium hydrate, lye

F.4.3.1 Summary

Sodium hydroxide (NaOH) is a chemical that may be used in the transportable chemical treatment systems as a treatment reagent. Environmental fate data suggest that sodium hydroxide is soluble in water and is not likely to be persistent in the environment.

F.4.3.2 Chemical Identity

Table F.4.3-1 presents the relevant chemical identity information for sodium hydroxide.

F.4.3.3 Physical-Chemical Properties

Table F.4.3-2 presents a summary of physical and chemical properties.

F.4.3.4 Environmental Fate and Transport

Limited environmental data are available for sodium hydroxide [85]. Sodium hydroxide does not volatilize from soils or water. Any solid particles released into air will under go wet deposition to earth. Sodium hydroxide is appreciably soluble in water. It will raise the pH of soils and groundwater. On acidic soils and in acidic groundwater sodium hydroxide will be neutralized to form sodium chloride and water. If deposited on surface soils it will absorb carbon dioxide from air and form water soluble sodium bicarbonate and sodium carbonate. Thus, sodium hydroxide will not be persistent in soils and water.

Table F.4.3-1. Chemical Identification Information—Sodium Hydroxide

CAS Registry No.	1310-73-2
Type	Treatment chemical
Molecular Formula	NaOH
Molecular Weight	40
Other Hazardous Chemicals in Mixture	Not applicable

Table F.4.3-2. Physical-Chemical Properties—Sodium Hydroxide

Physical Form/Color	White solid
Odor	None
Relative Vapor Density (to air)	Not applicable
Vapor Pressure	Not applicable
Boiling Point	1,390°C
Freezing Point	No information
Flash Point	Not applicable
Stability	Stable; store in corrosion-proof area in tightly-closed container.
Water Solubility	>10%; appreciable
Hydrolysis Products	Does not hydrolyze. Dissolves and is neutralized in acidic water to sodium chloride, water, and reacts with CO_2 to give sodium carbonate.
Flammability/Combustibility	None
Decomposition Temperature	Not applicable
Thermal Decomposition Products	Not applicable

F.4.4 Sodium Hypochlorite (NaOCl)

Synonym: household bleach

F.4.4.1 Summary

Sodium hypochlorite (NaOCl) solution, normally 10-15 percent in water with about 0.50-1.00 percent excess NaOH for stability control, is available commercially as bleach and may be used as a decontaminating solution in the chemical treatment process. Environmental fate data suggest that sodium hypochlorite is not likely to be persistent in the environment.

F.4.4.2 Chemical Identity

Table F.4.4-1 presents the relevant chemical identity information for sodium hypochlorite.

F.4.4.3 Physical-Chemical Properties

Table F.4.4-2 presents a summary of physical and chemical properties.

F.4.4.4 Environmental Fate and Transport

Limited environmental data were available for sodium hypochlorite. However, since sodium hypochlorite is completely soluble in water, it is not very persistent in moist air, soil, or aquatic systems. It is a good oxidizing agent and chlorinates organics. Under acidic conditions it decomposes to water and sodium chloride.

Table F.4.4-1. Chemical Identification Information—Sodium Hypochlorite

CAS Registry No.	7681-52-9
Type	Treatment chemical
Molecular Formula	NaOCl
Molecular Weight	74.44
Other Hazardous Chemicals in Mixture	Not applicable

Table F.4.4-2. Physical-Chemical Properties—Sodium Hypochlorite

Physical Form/Color	Clear, light yellow liquid
Odor	Chlorine
Relative Vapor Density (to air)	Not applicable
Vapor Pressure	Not applicable
Boiling Point	100°C (water)
Freezing Point	No information
Flash Point	Not applicable
Stability	Stable in alkaline water solution; avoid storage with other household chemicals, vinegar, acids, and ammonia.
Water Solubility	Complete solubility in cold water
Hydrolysis Products	Stable in alkali. Under acidic conditions decomposes to water and chloride.
Flammability/Combustibility	Non-flammable or explosive
Decomposition Temperature	Decomposed by hot water
Thermal Decomposition Products	Chlorine and other chlorinated species

F.4.5 t-Butyl Alcohol

Synonyms: 2-methyl-2-propanol, tertiary butanol, trimethyl carbinol

F.4.5.1 Summary

Tertiary butyl alcohol is a chemical which may be used in the transportable chemical treatment systems. Limited environmental fate data suggest that t-butyl alcohol is miscible with water and is not likely to be persistent in the environment.

F.4.5.2 Chemical Identity

Table F.4.5-1 presents the relevant chemical identity information t-butyl alcohol.

F.4.5.3 Physical-Chemical Properties

Table F.4.5-2 presents a summary of physical and chemical properties.

F.4.5.4 Environmental Fate and Transport

Limited environmental data were available for t-butyl alcohol. t-Butyl alcohol degrades in air by reaction with photochemically produced hydroxyl radicals. It can also be reoved from air by wet deposition back to earth. t-Butyl alcohol is miscible with water and may volatilize from water or wet soils [89]. It does not sorb to soils because of its solubility in water. It can volatilize from dry soils and will undergo wet deposition back to earth. It is reasonable to assume that it will not be very persistent in moist air, soil, or aquatic systems. There is extensive literature that shows t-butyl alcohol is readily biodegraded in soil and groundwater under aerobic conditions with an estimated half-life of 20 days in soils and about 1-4 days in rivers and groundwater. [87,88,128].

Table F.4.5-1. Chemical Identification Information—t-Butyl Alcohol

CAS Registry No.	75-65-0
Type	Treatment chemical
Molecular Formula	$(CH_3)_3COH$
Molecular Weight	74.1
Other Hazardous Chemicals in Mixture	Not applicable

Table F.4.5-2. Physical-Chemical Properties—t-Butyl Alcohol

Physical Form/Color	Colorless liquid or crystals
Odor	Camphor-like odor
Relative Vapor Density (to air)	2.5
Vapor Pressure	31 mm Hg at 20°C, 44 mm Hg at 26°C
Boiling Point	83°C
Henry's Law Constant, K_H	Ca. 10^{-5} atm-m^3/mol (estimated) [89]
Freezing Point	25.5°C
Flash Point	11.1°C
Stability	Flammable, store in a cool dry place
Water Solubility	Miscible with water
Reactivity	Materials to avoid: acids, acid chlorides, acid anhydrides, oxidizing agents,
Hydrolysis Products	Not applicable
Flammability/Combustibility	Flammable and combustible. Vapors may travel considerable distance to source of ignition and flash back. Container explosion may occur under fire conditions.
Decomposition Temperature	Autoignition temperature 480°C
Thermal Decomposition Products	Carbon monoxide and carbon dioxide

F.5 Chemical Agent Treatment Waste Products

F.5.1 Summary

Products of neutralization of chemical agents are considered hazardous waste by US DOT regulations. The major components of these wastes are MEA, sodium hydroxide, chloroform, and t-butyl alcohol, which are the treatment chemicals. The products of chemical agent neutralization are dissolved in these materials and because of the large excess of treatment chemicals used the concentrations of agent degradants are quite low. With some exceptions component chemicals of these wastes are not expected to be persistent in the environment. Upon release to the environment, the treatment chemicals will have a greater impact rather than the agent degradants because of the quantities involved. As discussed in previous sections, the treatment chemicals themselves are not persistent in the environment.

F.5.2 Chemical Identity

There are mainly three categories of wastes generated in this program:

- Industrial chemicals
- Munitions Management Device (MMD) treated wastes
- Rapid Response System (RRS) wastes

Industrial chemicals will be repackaged and transported to a licensed transportation, storage, and disposal facility (TSDF).

The MMD wastes are generated as described below. Scientists at the Edgewood Chemical and Biological Center have performed laboratory scale neutralization of GB, VX, and HD. They have reported the identities and concentrations of the compounds contained in the neutralization waste [133].

GB is neutralized with a mixture of MEA and water. The compounds identified in this neutralization are listed in Table F.5.2-1. VX is neutralized with a mixture of MEA and sodium hydroxide. The compounds identified in this neutralization are listed in Table F.5.2-2. HD is neutralized with a mixture of MEA and water. The compounds identified in this neutralization are listed in Table F.5.2-3.

Phosgene is neutralized with aqueous sodium hydroxide and the neutralization products are shown in Table F.5.2-4.

Chemical agents contained in CAIS items are neutralized at the RRS sites. Chemical agents contained in CAIS items are neutralized with solutions of 1,3-dichloro-5,5-dimethylhydantoin in chloroform and t-butyl alcohol. The products of neutralization of HD, HN-1, HN-3, and L are given in Table F.5.2-5 [134].

The products of neutralization of chemical agents are unique to this program and data on their environmental transport and fate are not yet available. Thus, some of the products of neutralization in each of the tables below have been placed in different categories and the fate of each type of compounds is speculated based upon the known chemistry of similar compounds.

Compounds regulated by RCRA have also been included in the table. However, the fates of these compounds are not discussed here because of their very low concentrations. Also, the fate of these compounds have been well documented by the USEPA and this information may be found readily on the USEPA internet web site, http://earth1.epa.gov:80/chemfact/ and at http://www.atsdr.cdc.gov/toxfaq.html.

F.5.3 Environmental Fate and Transport

Among the MMD neutralent wastes compounds marked "RA" are the residual chemical agents. The concentrations of the chemical agents themselves will have been reduced to very low concentrations. The environmental fate of these agents have been discussed earlier in this appendix.

Compounds marked "TC" are the treatment chemicals used to neutralize the chemical agents. These form the largest fraction of the wastes (> 90%). The fate of these chemicals have been discussed in the prvious sections.

Among the waste products listed under GB and VX some are marked "OP". These are organophosphate esters. The molecular structures of these compounds are very similar to the chemical agents themselves which are also organophosphorus esters. For example, isopropyl methylphosphonic acid (IMPA) was encountered in the discussion on degradation of sarin. The key structural feature of this molecule is the P--O[CH(CH3)$_2$] bond. IMPA degrades to MPA by cleavage of this bond. Similarly, the GB neutralization product, "GB-MEA Complex", also contains a P--O[CH(CH3)$_2$] and a P—$OCH_2CH_2NH_2$ bond. Thus, it is reasonable to expect this compound would degrade to MPA by the hydrolysis of both P--O bonds. Similar arguments apply to the organophosphorus compounds generated by neutralization of VX.

Compounds marked "OS" are organosulfurous compounds. These are organic sulfides similar to thiodiglycol and will most likely meet the same fate. One of the VX neutralization products is NaThiol. This will probably dissolve in groundwater and become 2-diisopropylaminoethanethiol. This compound has been discussed in the section on VX degradation above. It will oxidize to the disulfide, which is a very stable compound under environmental conditions.

The compound N-(2-hydroxyethyl)thiomorpholine is a ring compound with sulfur and nitrogen atoms in the ring. It has been shown that a similar compound, morpholine, undergoes biodegradation to monoethanolamine and then to triethanolamine [83]. Therefore, it is reasonable to expect similar fate for the HD waste product also.

Table F.5.2-1 Composition of Sarin (GB) Neutralent Wastes from Bench-Scale Tests of the Munitions Management Device—Version One[a]

Waste Component	Concentration	Category
GB	ND (<25 ppb)	RA
Major Constituents	**Wt%**	
Water	49.4-49.9	
Monoethanolamine (MEA)	33.9-40.3	TC
2-hydroxyethylammonium O-isopropyl methylphosphonate salt	0.7-8.5	OP
Monoethanolamine hydrofluoride salt	0.4-4.6	TC
O-isopropyl O'-(2-aminoethyl)methylphosphonate (GB-MEA complex)	0.3-3.0	OP
Minor Constituents (< 1%)	**Wt%**	
Diisopropyl methylphosphonate (DIMP)	0.03-0.36 wt %	OP
Tributylamine (TBA)	0.2-0.017 wt %	
1,3-diisopropylurea (DIPU)	45-530 ppm	
1,3-diisopropylthiourea (DIPTU)	17-200 ppm	
2-hydroxyethylammonium methylphosphonate salt	400-800 ppm	OP
Other methylphosphonates	<100 ppm	OP
RCRA TCLP Constituents		
Organics	**mg/l**	
Benzene[b]	6.5-6.8	
Hexachlorobutadiene[c]	1.0-1.6[f]	
2,4-dinitrotoluene[c]	0.2-1.6[f]	
Hexachlorobenzene[c]	0.2-1.6[f]	
Methyl ethyl ketone (MEK)[d,e]	0.29-0.54[f]	
Metals:	**ppm**	
Arsenic[d]	0.66-0.76	
Barium[d]	ND-0.75	
Chromium[d]	410-1080	
Lead[d]	550-1300	
Nickel[e]	410-500	

[a] Treatment reagent: water (55 percent), MEA (45 percent)
[b] RCRA toxicity characteristic component concentration greater than TCLP regulatory level.
[c] RCRA toxicity characteristic components. Quantitation limits were above TCLP regulatory limits.
[d] RCRA toxicity characteristic component concentration less than TCLP regulatory limit
[e] Not a TCLP constituent. Included because it is listed in Appendix VIII—Hazardous Constituents in 40 CFR 261.

ND—not detected
Wt %—percent by weight
TCLP—Toxicity characteristic leaching procedure (40 CFR 261.24)
RA—Residual Agent
TC—Treatment Chemical
OP—Organophosphorus compound
OS—Organosulfur compound

Source: Reference [133].

Table F.5.2-2. Composition of VX Neutralent Wastes from Bench-Scale Tests of the Munitions Management Device—Version One[a]

Waste Component	Concentration	Category
VX	ND (<1 ppm)	RA
Major Constituents	**Wt%**	
Monoethanolamine (MEA)	77.6-83.0	TC
Water	6.9-7.0	
Sodium hydroxide	4.2–6.3	TC
Sodium 2-diisopropylaminoethanethiolate (NaThiol)	1.4–0.5	OP
Sodium O-ethylmethylphosphonate (NaEMPA)	0.6-2.0	OP
Sodium O-(2-aminoethyl) methylphosphonate (NaAEMPA)	0.5-1.8	OP
Minor Constituents (<1 %)	**Wt%**	
Disodium methylphosphonate (Na_2MPA)	0.15-0.5	OP
Bis-(2-diisopropylaminoethyl)sulfide (SULFIDE)	0.22-0.71	OS
Bis-(2-diisopropylaminoethyl)disulfide (DISULFIDE)	0.13-0.41	OS
2-diisopropylaminoethyl ethyl sulfide	0.03-0.09	OS
1,3-dicyclohexylurea	0.1-0.35	
Ethanol	0.2-0.7	
Unquantified identified products[b]	0.4-1.0	
RCRA TCLP Constituents		
Organics:	**mg/l**	
Benzene[c]	1.0-7.5[e]	
Carbon tetrachloride[c]	<1.0[e]	
1,2-dichloroethane[c]	<1.0[e]	
1,1-dichloroethylene[c]	<1.0[e]	
Tetrachloroethylene[c]	<1.0[e]	
Trichloroethylene[c]	<1.0[e]	
Vinyl chloride[c]	<1.0[e]	
Metals:	**ppm**	
Chromium[d]	0.38-0.44	
Lead[d]	1.2-1.4	
Selenium	<1.0-4.1	

[a] Treatment reagent: MEA (85 percent), water (7.5 percent), sodium hydroxide (7.5 percent)
[b] Compounds identified: cyclohexylamine (CHA); 2-diisopropylamino ethanol (DIPAE); 2-diisopropylamino ethanethiol (VX thiol); 2-(diisopropylamino)ethyl sulfide (DIPAES); chloromethyl-2-(diisopropylamino) ethyl sulfide (DIPAMS); N-2-[(chloromethylthio) methylthio]ethyl-N-isopropyl-2-propanamine; Bis(2- diisopropylaminoethyl)sulfide (VX sulfide); Bis(2- diisopropylaminoethyl) disulfide (VX disulfide); N-2-0[(2-diisopropylamino)ethylthiomethylthio ethyl-N-isopropyle-2-propanamine (VX Me disulfide); Ethylene glycol (EG); N-2-hydroxyethyl methylphosphoramidate (VX-N-MEA)
[c] RCRA toxicity characteristic component concentration greater than TCLP regulatory level.
[d] RCRA toxicity characteristic component concentration less than TCLP regulatory limit.

ND—not detected
Wt %—percent by weight
TCLP—Toxicity characteristic leaching procedure (40 CFR 261.24)
RA—Residual Agent
TC—Treatment Chemical
OP—Organophosphorus compound
OS—Organosulfur compound

Source: Reference [133].

Table F.5.2-3. Composition of Mustard (HD) Neutralent Wastes from Bench-Scale Tests of the Munitions Management Device—Version One[a]

Waste Component	Concentration	Category
HD	ND (<50 ppb)	RA
Major Constituents	**Wt%**	
Monoethanolamine (MEA)	67-89	TC
Water	8.9-9.9	
Monoethanolamine hydrochloride	0.9-13.8	TC
N-(2-hydroxyethyl)thiomorpholine (HETM)	0.6-9.1	OS
Bis-[(2-hydroxyethylamino)ethyl] sulfide (HEAES and other organic sulfides)	0.05-1	OS
Minor Constituents (< 1%)	**Wt%**	
1,4-dithiane	0.008-0.16	OS
Chlorinated thiophenes	<1[e]	OS
RCRA TCLP Constituents		
Organics:	**mg/l**	
Tetrachloroethylene[b]	2.2-2.6	
Trichloroethylene[b]	1.4-1.6	
Vinyl chloride[b]	5.8-6.9	
Hexachlorobutadiene	2.0-3.3[e]	
2,4-dinitrotoluene	2.0-3.3[e]	
Hexachlorobenzene	2.0-3.3[e]	
1,1-dichloroethylene[c]	0.13-0.15	
Chloroform[c]	0.14-0.2	
Methyl ethyl ketone (MEK)[c,d]	0.33-0.37	
Metals:	**ppm**	
Arsenic[c]	0.14-0.23	
Chromium[c,d]	0.531-0.62	
Nickel[d]	0.13-0.15	
Selenium[b]	3.0-3.6	

[a] Treatment reagent: water (10 percent), MEA (90 percent)
[b] RCRA toxicity characteristic component concentration greater than TCLP regulatory level.
[c] RCRA toxicity characteristic component concentration less than TCLP regulatory limit
[d] Not a TCLP constituent. Included because it is listed in Appendix VIII—Hazardous Constituents in 40 CFR 261.

Wt%—percent by weight
TCLP—Toxicity characteristic leaching procedure (40 CFR 261.24)
RA—Residual Agent
TC—Treatment Chemical
OP—Organophosphorus compound
OS—Organosulfur compound

Source: Reference [133].

Table F.5.2-4. Composition of Phosgene Neutralent Wastes from Bench-Scale Tests of the Munitions Management Device—Version One[a]

Waste Component	Percent by Weight	Category
Water	90	
Sodium hydroxide (NaOH)	8-9	TC
Sodium carbonate (Na_2CO_3)	1-2	
Sodium chloride (NaCl)	1-2	

[a] Treatment reagent: water (90 percent), sodium hydroxide (10 percent)

Source: Reference [133]

TC—Treatment Chemical

Table F.5.2-5. Composition of Neutralent Wastes from the Rapid Response System[a]

Waste Component	Category	Treatment Process		
		Blue (percent by weight)	Red (percent by weight)	Charcoal or Charcoal-L (percent by weight)
Chloroform	TC	54.5–55.5	60–61	50–84
t-butyl alcohol	TC	26–27	17–20	0–24
Water		2.2–2.4	1.7–1.9	0–1
Dichlorodimethylhydantoin (unreacted)(DCDMH)	TC		0–4.6	0–7
Chlorodimethylhydantoin (CDMH)	TC	2.1–5.9	1.9–5.6	2–6
5,5-dimethylhydantoin (DMH)	TC	1–3	0–4.6	0–3
Chlorinated sulfoxides (diethyl and ethylvinyl)	OS	5.4–7.6	0.6–2.1	0–0.4
Chlorobutanes and chlorobutenes	RCRA	2.4–3.4	1.2–4.6	0–4
Chlorinated sulfones (diethyl and ethylvinyl)	OS	0–0.1	0–0.06	0–0.3
1,1,2-trichloroethane	RCRA	0–0.015	0–0.23	0–0.025
Tetrachloroethane[b]	RCRA	0–0.025	0–0.2	0–0.022
Bis-(2-chloroethyl)amine	TC		0–1	0–0.5
Chlorovinylarsonic acid	RA		0–2.6	0–3
Acetaldehyde and chloroacetaldehyde			0–0.5	
Polychlorinated diethyl sulfides and polychlorinated ethylvinyl sulfide	OS			0–2
Dichloroethane[c]	RCRA			0–0.03
Pentachloroethane	RCRA			0–0.03
Hexachloroethane[c]	RCRA			0–0.01
Chloral hydrate				0–0.7
Additional RCRA TCLP Constituents *Organics*: Carbon tetrachloride; 1,1-dichloroethylene; tetrachloroethylene; trichloroethylene; vinyl chloride *Metals*: Arsenic, barium, cadmium, chromium, lead, mercury, nickel[d], selenium, silver		Expected to be present in waste. Data on concentrations not yet available. Toxic characteristic metals have been assumed to be impurities in chemical agents. All metals may not be present in all wastes. Lewisite contains arsenic. Data on concentrations not yet available.		

[a] RCRA characterization of the neutralent waste stream will be completed using analytical data obtained from bench-scale demonstrations conducted at the Edgewood Chemical and Biological Center (ECBC), Aberdeen Proving Ground, MD.
[b] May be either isomer, 1,1,1,2-tetrachlorethane or 1,1,2,2-tetrachlorethane.
[c] RCRA TCLP constituents.
[d] Not a TCLP constituent. Included because it is listed in Appendix VIII – Hazardous Constituents in 40 CFR 261.
TCLP – Toxic characteristic leaching procedure (40 CFR 261.24)
RA—Residual Agent
TC—Treatment Chemical
OP—Organophosphorus compound
OS—Organosulfur compound.
Source: Reference [134]

F.6 Glossary

Abiotic: Occurring in the absence of living organisms.

Acetylcholinesterase: The enzyme which degrades acetylcholine, thus preventing it from continuing to transmit a signal from one nerve to another nerve, muscle, gland or internal organ.

Aerosol: The dispersion of a liquid or solid in a gas; a fine mist.

Agent: Something that causes an effect in a living organism. This effect can be either beneficial or detrimental. Examples of agents include chemical substances (e.g., penicillin, arsenic), biological organisms (e.g., bacteria), and forms of energy (e.g., x-rays, radiant heat).

Alkylating agent: A chemical that can irreversibly add a carbon-hydrogen structure to a protein or DNA molecule, thereby altering its molecular structure and perhaps disrupting its function.

Aquatic fate: What happens to a chemical in water. Aquatic fate processes include (but are not limited to) volatilization and hydrolysis.

Arsenical: A chemical that has as one of its components the element arsenic.

Atmospheric fate: What happens to a chemical in air. Atmospheric fate processes include (but are not limited to) photolysis, hydrolysis, and dispersion.

Bioaccumulation: The tendency for a chemical to accumulate in an organism over time as a result of uptake from all routes of exposure.

Bioconcentration: The tendency for a chemical to be at a higher concentration in an organism than in its surrounding aquatic environment.

Biodegradation: The breakdown of a compound by living organisms (especially by bacteria or fungi).

Blistering agent: Vesicant; a chemical that causes the formation of blisters on the skin following dermal contact with its vapors or liquid form.

Carcinogen: An agent that is capable of producing cancer.

CAS Registry No.: An unique identifying number assigned to each chemical by the American Chemical Society's Chemical Abstracts Service.

Choking agent: A chemical that causes difficulty in breathing by irritating or constricting the airways.

Combustible: Having a flash point of 38°C or greater.

Cumulative: Building up over time or with repeated exposures.

Dechlorination: The removal of chlorine atom(s) from a molecule.

Defecation: The discharge of feces from the bowels.

Degradation: Breakdown, decomposition.

Deposition: The settling out of a chemical substance from the air onto the ground or in the lung.

Dermal: Pertaining to the skin.

Detoxification: The process by which a chemical is made less toxic, usually achieved by metabolism or by abiotic degradation of the chemical.

Dispersion: The wide distribution of a chemical substance in air, water, or soil.

Dissolution: The dispersion of a chemical in water or other solvents.

Fate and transport: A phrase used to describe how a chemical moves through the environment (e.g., from soil to water) and what happens to it in the environment (e.g., it undergoes hydrolysis or volatilization).

Flammable: Easily ignitable and capable of burning rapidly. A flammable solid will ignite readily and continue to burn, or may cause fires due to friction or retained heat from manufacturing/processing. A flammable liquid has a flash point below 38°C. A flammable gas forms an ignitable mixture with air at a concentration of 13 percent by volume or less.

Flash point: The lowest temperature at which the vapor above a liquid can be made to quickly ignite.

Half-life: The time required for the concentration of a chemical to be reduced to one-half of its original concentration by metabolism, abiotic degradation, or other removal/reduction processes.

Hallucination: A false sensation (sight, sound, taste, smell, or touch) that has no basis in reality.

Hydrolysis: The decomposition of a chemical by its reaction with water.

Lacrimation: The secretion of tears from glands above the eyeball.

Lacrimator: An agent that induces the secretion of tears from glands above the eyeball.

Metabolism: The chemical reactions that occur in the body, including the synthesis of large molecules like protein and DNA, and the breakdown of food and foreign chemicals.

Miscible: Capable of being mixed.

Mustard gases: A family of volatile chemicals that cause the formation of blisters on exposed skin.

Nerve agent: A chemical that interferes with the normal functions of the central and/or peripheral nervous systems.

Organophosphate: A chemical agent which is composed of carbon, hydrogen, phosphorus, and oxygen in a particular molecular arrangement; members of this class of chemicals inhibit acetylcholinesterase to varying degrees.

Permeable: The property of allowing a substance (e.g., a liquid) to filter through.

Photochemical: Pertaining to the reaction of a chemical with the energy of light.

Photolysis: The light-induced breakdown of a chemical.

Physical-chemical properties: Characteristics of a chemical such as appearance, odor, molecular weight, solubility, and boiling point.

Relative vapor density: A measure of the "heaviness" of a vapor compared, in this document, to the "heaviness" of air.

Solubility: The degree to which a chemical disperses in another substance (e.g., water, lipid [fat], chloroform).

Terrestrial fate: What happens to a chemical on land and especially in the soil. Terrestrial fate processes include (but are not limited to) evaporation, hydrolysis, and degradation by living organisms.

Thermal: Pertaining to heat.

Toxic: Poisonous; capable of disrupting the normal function of a cell, an organ, or an organism as a result of sufficient exposure.

Vapor: A chemical substance in the gaseous state at a temperature below the substance's boiling point.

Vapor pressure: A measure of the tendency of a liquid or a solid to change into a gas.

Vesicant: Blistering agent; a chemical that causes the formation of blisters on the skin following dermal contact with its vapors or liquid form.

Volatility: The degree to which the solid or liquid state of a chemical passes into the gaseous state at normal temperature and air pressure.

Volatilization: The passing of a chemical from the solid or liquid state into the gaseous state.

F.7 Acronyms, Abbreviations, and Units of Measure

μg	Microgram, a unit of mass equal to 1/1000 of a milligram or one-millionth of a gram
μg/kg/day	Microgram(s) per kilogram per day, a unit for daily doses or exposures
$\mu g/m^3$	Microgram(s) per cubic meter, a unit of concentration in air
°C	Degree(s) Celsius, a unit of temperature
AC	Hydrogen cyanide
ACGIH	American Conference of Governmental Industrial Hygienists
BBC	Bromobenzyl cyanide; also CA
BCF	Bioconcentration factor
BZ	3-Quinuclidinyl benzilate
CA	Bromobenzyl cyanide; also BBC
CAS	Chemical Abstracts Service
CG	Phosgene
CK	Cyanogen chloride
CN	Chloroacetophenone
CNB	Chloroacetophenone in benzene and carbon tetrachloride
CNS	Chloroacetophenone and chloropicrin in chloroform
DCDMH	1,3-Dichloro-5,5-dimethylhydantoin
DM	Adamsite
DMA	Dimethylamine
DNA	Deoxyribonucleic acid
DP	Diphosgene
EMPA	Ethyl methylphosphonic acid
EPA	Environmental Protection Agency
g/ft^3	Gram(s) per cubic foot, a unit of air concentration – convert to mg/m3 in doc
g/L	Gram(s) per liter, a unit or water or air concentration
GA	Tabun
GB	Sarin
GD	Soman
H	Sulfur mustard; also HS
HD	Distilled sulfur mustard
HL	A mixture of distilled sulfur mustard (HD) and lewisite (L)
HN-1	Nitrogen mustard 1
HN-2	Nitrogen mustard 2
HN-3	Nitrogen mustard 3
HS	Sulfur mustard; also H

HT	A mixture of distilled sulfur mustard (HD) and agent T (T)
IC_{50}	Mediating incapacitating concentration
IMPA	Isopropyl methylphosphonic acid
kg	Kilogram, a unit of mass
L	Liter, a unit of volume
L	Lewisite
LC_{50}	Median lethal concentration
LD_{50}	Median lethal dose
MEA	Monoethanolamine
mg	Milligram, a unit of mass equal to 1/1000 of a gram
mg/kg	Milligram(s) per kilogram of body weight, a unit used to normalize doses or exposures to body size
mg/kg/day	Milligram(s) per kilogram per day, a unit for daily doses or exposures
mg/L	Milligram(s) per liter, a unit of concentration in water or air
mg/m^3	Milligram(s) per cubic meter, a unit of concentration in air
$mg\text{-}min/m^3$	Milligram(s) a minute per cubic meter; the product of units of concentration and time: $mg/m^3 \times min$. The use of this unit lets one compare exposures of different durations. This comparison is based on the fact that a short exposure to a high concentration produces the same response as a long exposure to a low concentration.
mL	Milliliter, a unit of volume equal to 1/1000 of a liter
mm	Millimeter, a unit of length equal to 1/1000 of a meter
mm Hg	Millimeter(s) of mercury, a unit of pressure; 760 mm Hg is "standard" air pressure at 0°C at sea level
MPA	Methylphosphonic acid
NaOCl	Sodium hypochlorite
NaOH	Sodium hydroxide
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No observed adverse effect level
OSHA	Occupational Safety and Health Administration
PEIS	Programmatic Environmental Impact Statement
PEL	Permissible exposure limit
PMPA	Pinacolyl methylphosphonic acid
ppm	Part(s) per million, a unit of concentration in water, air, or soil
PS	Chloropicrin
T	bis(2-(2-Chloroethylthio)-ethyl) ether
VX	O-Ethyl-S-(2-diisopropylaminoethyl)-methyl phosphonothiolate

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Appendix G

Other Treatment Technologies and Systems

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Appendix G

Other Treatment Technologies and Systems

Although direct, fuel-fired combustion, or incineration, is the most popular method of waste disposal in commercial industry; alternative disposal methods are being evaluated worldwide. Many of these technologies are only conceptual, but some are being, or have been, tested. These "emerging" technologies may be applicable to the destruction of non-stockpile chemical warfare materiel (CWM).

This appendix describes generic pre-treatment (§G.3), generic treatment technologies (§G.4), and specific, commercially available treatment technologies (§G.6) that could be incorporated into an alternate, integrated system for the treatment of non-stockpile CWM. Such alternatives would have to be developed as a consequence of the Army not proceeding with the transportable treatment systems described in Chapter 2. An alternative could also be developed to supplement the transportable treatment systems.

The discussions of the technologies presented in this chapter are based on publicly available sources of information. In some instances, proprietary development of certain technologies is being undertaken by commercial industry. The discussions identify developers, patent holders, and licensees whenever possible. Not every possible option that is available for treatment system development, or that may yet be developed, is represented in this appendix despite efforts to be inclusive. The inclusion of the technologies in this chapter does not represent Army endorsement of any technology.

While this chapter emphasizes those technologies for accessing and treatment of chemical agents in non-stockpile CWM, the technologies described could also be developed to access and treat industrial chemicals in non-stockpile CWM, or treat the neutralent wastes generated from the treatment of chemical agents by the transportable chemical treatment systems described in Chapter 2.

In this appendix, technologies are categorized into four distinct areas:

- ***Pre-Treatment*** – Operations that prepare and reconfigure feeds and materials for the treatment technologies. Pre-treatment technologies usually include gaining access to the internal chemical fills but also include preparing feed for treatment such as material segregation, size reduction, and chemical or thermal pre-treatments.
- ***Treatment*** – Operations that detoxify chemical agents and deactivate explosive materials.
  - Thermal – Treatment using heat. Thermal treatment is accomplished by initiating a reaction under high temperature conditions. The heat alone can and does destroy

the chemicals but the reactive environment inside the furnace defines the reaction products.

  - Chemical – Treatment using a chemical reagent. Liquids, slurries, or solids are mixed with a reagent (consisting of one or more chemicals) in a reactor.

- ***Post-Treatment*** – Operations that change the chemical nature of waste streams from treatment to remove any remaining hazardous characteristics.
- ***Effluent Management*** – Operations that change the physical nature of streams from post-treatment to allow final disposition.

These operations are preceded manual preparation such as unpacking and feeding. Any alternative process would typically require various pieces of equipment and processing strategies under each of these categories to be combined into an integrated process.

G.1 Summary

Many industrial technologies could be applied to pre-treatment, treatment, and post-treatment of non-stockpile CWM. Commercial industry has made the effort to develop only a few, while others may be developed by academic groups or entrepreneurs. Most are standalone systems designed for either some method of pre-treatment or for a combination of treatment and post-treatment. These standalone unit operations would have to be fully integrated into a process for treatment of CWM that includes, where needed, pre-treatment, treatment, post-treatment, and effluent management. Any system must be capable of processing all applicable CWM configurations by remote control inside a transportable structure that provides appropriate vapor containment and, where necessary, explosion containment.

G.1.1 Challenges

Any alternative integrated system that is used to treat non-stockpile CWM with an alternative treatment technology must overcome a number of special challenges associated with the destruction of CWM.

The system must be capable and versatile enough to process all expected CWM items in a variety of conditions. Non-stockpile CWM items are identified in Appendix B. CWM consist of items with various quantities and kinds of chemical fills existing in varying concentrations and in different solutions. Chemicals may be liquid, solid, or gaseous. CWM includes whole and partial items as well as loose component hardware. The CWM may be pristine or highly decomposed (see Appendix B). Internal and external dimensions may vary drastically for munitions of the same design. Excessive decomposition can weaken the structural integrity of the munition making the structure fragile so shock and vibration of munition during operations must be minimized.

The system must be compatible with the operational safety requirements associated with processing CWM. The greatest operational challenge is adapting a technology to work under the vapor and explosion containment protocols necessary for safe destruction of CWM. Pre-treatment accessing and treatment require vapor containment structures to prevent release of agent vapor. In addition, certain operations will require explosion containment. Vapor containment requires sealed structures with a method of treating agent vapor release. Explosion containment is much more difficult, but is not required for CWM that are not explosively configured. Explosion containment requires a hardened structure that can withstand the destructive force of a detonation. This includes shock, overpressure, and heat as well as fragmentation (shrapnel).

Any chemical agent process must be compatible with the chemical agent monitoring equipment. Any treatment technology must be capable of verifying agent destruction and, where applicable, verifying explosives deactivation using a validated sampling and analysis test method. The type and quantity of every compound in each effluent streams must be (or eventually be) characterized.

G.1.2 Pre-Treatment (Generic)

The techniques for pre-treatment accessing of non-stockpile CWM in the planned transportable units currently under development by the Army include crushing of glass vials and bottles in the Rapid Response System (RRS); drills, saws, and punches in the Munitions Management Devices (MMDs); and explosives supplemented, controlled detonation in the Explosive Destruction System (EDS).

The selection of one or more accessing techniques is dependent on system integration with the treatment technology. Of the many industrial accessing techniques possible, only a few have been adapted for accessing CWM. Accessing technologies are classified as cutting, fragmenting, or separation as shown in Table G-1. All of these techniques have experience with accessing chemical or conventional munition except chemical/ electrochemical, electromagnetic radiation, and ultrasonic.

G.1.3 Treatment (Generic)

Treatment technologies can be categorized into classes. A list of generic treatment technologies is provided in Table G-2. Thermal systems use heat treatment (furnaces), chemical systems use reagents, biological systems use living organisms, and irradiation uses only light. Thermal treatments (furnaces) are a function of three distinctive features: the heating method, the equipment configuration, and the reactive environment. Chemical treatments are mostly governed by the type of reagent or reagents used. Discussion of each of these features is provided in Section G.4.

Table G-1. Generic Pre-Treatment Accessing Techniques

Class	Description
Cutting	Penetration or separation by means of a sharp instrument or by the physical removal, disturbance, or ripping of material. • Machining • Chemical/Electrochemical • Electromagnetic Radiation • Explosive • Fluid • Thermal • Ultrasonic
Fragmenting	Fracturing of the material either into smaller pieces or by rupturing. • Cryogenic embrittlement • Controlled detonation
Separating	Disassembly, or reverse assembly, of components.

Table G-2. Generic Treatment Technologies

Class	Description		
Thermal	Use of heat to decompose chemicals		
	Heating Methods	**Equipment Configurations**	**Chemical Reactions**
	• Direct, Fuel-Fired (Combustion) • Induction • Plasma Arc • Radiation	• Static Furnace • Rotary Furnace • Tunnel Furnace • Fixed Bed Reactor • Fluidized Bed Furnace • Molten Media Furnace • And others	• Oxidation • Reduction (hydrogenolysis) • Hydrolysis • Reaction with Sulfur
Chemical	The addition of reagents, sometimes with catalysts or activators at various temperatures and pressures, to detoxify chemicals. Includes electrochemical and photochemical technologies.		
	• Hydrolysis • Oxidation • Reduction • Dehalogenization	• Alcoholysis • Chlorolysis • Digestion/Dissolution • Metal and Metal Oxide Catalysis	
Biological	Biological organisms or enzymes to 'digest' biodegradable chemicals, converting them into less- or non-hazardous waste.		
Irradiation	Use of only radiation or light to decompose chemicals.		
Hybrids	Simultaneous integration of two or more treatment processes		

G.1.4 Commercially Available Treatment Technologies

Some treatment technologies are being (or have been) developed commercially. Potential treatment technologies are listed in Table G-3 (for thermal) and in Table G-4 (for chemical) with some of their important features. The ranges of reported operating temperatures, pressures, and the physical states of the input and effluent stream for various applications are listed in Table G-5.

The state of development of the various treatment technologies varies greatly. For example, some have been extensively used commercially in related operations, some have been patented, and some have yet to be demonstrated at full-scale. The general status of reported development is listed in Table G-5. Other features relevant to developmental considerations involving non-stockpile CWM are also listed in this table. This includes whether or not the technology has been used to treat chemical agent or other CWM components including explosive compounds, and whether a transportable system has been developed. The status of development and potential applicability to the Non-Stockpile Chemical Materiel Project (NSCMP) is shown in Table G-6 as indicators of the time and costs that may be required to develop a future integrated and operational system.

Table G-3. Commercial Thermal Treatment Technology Features

Technology	Features
Adams Process (Reaction with Sulfur)	Elemental sulfur reactive environment Nitrogen gas blanket purge Carbon-sulfur polymer solid produced Energetic materials bench study
Catalytic Oxidation	Thermal oxidation catalytic enhancement Industrial use for treating low concentration volatile organic wastes Same principle as car catalytic converters
Direct, Fuel-Fired Combustion (Incineration)	Oxidizing reactive environment Broad historical application in Chemical Stockpile Disposal Program Treats metal parts and energetic materials Mobile unit used for sulfur mustard (HD) in Canadian Swiftsure project Primary incinerator requires secondary treatment process (e.g., afterburner)

Table G-3 (Concluded)

Technology	Features
Fixed-Bed Furnace Oxidation	Oxidizing reactive environment Can recycle off-gases in a batch-type configuration Commercial application includes treatment of several hazardous wastes, pesticides, and polychlorinated biphenyls Uses no flame or catalyst for thermal oxidation Packed ceramic bed
Fluidized-Bed Oxidation	Oxidizing reactive environment Solid suspended media provides thermal inertia, heat transfer, mixing, and reactive surface area Thermal oxidation catalytic enhancement Commercial use for hazardous waste treatment Slurried explosives treatment
Gas-Phase Chemical Reduction	Reducing reactive environment using steam and hydrogen Methane is primary off-gas Can recycle or recover process off-gases Used to treat organic wastes, including polychlorinated biphenyls in oil, water, and soil
Hydrogenation Processes	Reducing reactive environment using hydrogen Requires suitable catalyst Widely used in oil industry Produces methane as primary off-gas
Molten Metal Catalytic Extraction	Reducing and slightly oxidizing reactive environment Metal catalysts heated and melted Molten bath is material sink and heat moderator Off-gas contains hydrogen
Molten Salt Oxidation	Salts catalyze the reaction Molten bed acts as sink for reaction salts and temperature moderation Molten salts controls much of the acid gas production Pilot study to treat energetic materials
Plasma Arc Furnace	Uses an oxidizing, reducing, or steam reforming reactive environments Treats solids Energetic materials treated in laboratory tests
Steam Reformation	Agent is vaporized and re-forms with water in superheated steam Can recycle process effluents Off-gas production (hydrogen and methane) Can be used in other technologies and with or without catalysts

Table G-4. Commercial Chemical Treatment Technology Features

Technology	Features
Acid Digestion	Uses aqueous nitric acid as the reagent Can treat whole munition (disassembly not required) Can recycle or recover some waste materials Testing on munitions conducted
Chemical Reagent Neutralization	Performed with water, caustic, alcohol, monoethanolamine, and other reagents Pilot-scale operations planned for treating chemical stockpiles at Edgewood Chemical Activity and Newport Chemical Depot Broad historical application using hydrolysis and oxidizers Used in the Rapid Response System and Munitions Management Devices
Mediated Electrochemical Oxidation	Generates and uses reactive metal ions as a reagent Similar to organic compound synthesis using electric current passed through an electrochemical cell Can recycle/recover metal reagent, electrolytic acid, and brine Pilot plant using silver to treat energetic materials
Solvated Electron Reduction	Use of alkaline earth metals in anhydrous carrier solvent Can recycle or recover carrier solvent Energetics and agents treated in laboratory tests
Supercritical Water Oxidation	Water above its critical point with addition of oxidizing reagent (e.g., oxygen from air) High heat transfer and reaction rates Requires aqueous dilution of agent feed Pilot treatment of energetic materials
Wet Air Oxidation	Water below its critical point with addition of oxidizing reagent (e.g., oxygen from air) Treats dilute aqueous feed streams Many plants operating for other organic wastes Results in small organic compounds

Table G-5. Chemical Agent Treatment Technology Operating Parameters

Treatment Technology	Feed Physical State [a]	Temperature (°C)	Pressure [b] (kilograms per square centimeter)	Waste Streams [c]
Acid Digestion	S	49–71	atmospheric	G, L, S
Adams Process (Reaction with Sulfur)	G, L	135–1,538	atmospheric	G, S
Catalytic Oxidation	G, L	260–621	atmospheric	G, S
Chemical Reagent Neutralization	G, L, S	Ambient–93	atmospheric	G, L, S
Direct, Fuel-Fired Combustion (Incineration)	G, L, S	454–1,482	atmospheric	G, S
Fixed-Bed Oxidation	G	871–1,093	atmospheric	G, S
Fluidized-Bed Oxidation	G, L	599–1,010	atmospheric	G, S
Gas-Phase Chemical Reduction	G, L	871	1	G, L
Hydrogenation Processes	G, L	399–499	11–105	G, S
Mediated Electrochemical Oxidation	L, S	<100	atmospheric	G, L, S
Molten Metal Catalytic Extraction	G, L, S	1,371–1,649	1–2	G, S
Molten Salt Oxidation	G, L	599–1,160	atmospheric	G, S
Plasma Arc Furnace	G, L, S	1,482–16,649	atmospheric	G, S
Solvated Electron Reduction	G, L, S	(–)32–27	0–10	G, S
Steam Reformation	G, L	316–1,299	atmospheric	G, L, S
Supercritical Water Oxidation	L	343–599	225–281	G, L, S
Wet Air Oxidation	L	149–316	141	G, L, S

[a] G = gas; L = liquid or slurry; S = solid. Feed stream of chemical agent only, does not include other input process streams.

[b] Reported operating pressure (atmospheric pressure = about 1 kilogram per square centimeter).

[c] G = gas; L = liquid; S = solid. Waste streams are from agent treatment process and do not include post-treatment processing.

Table G-6. Applicability of Treatment Technologies to Non-Stockpile CWM

Technology	Agent Use[b]	Scale with Agent[c]	Scale without Agent[d]	Explosives Treatment[e]	"Other" Munition Components[f]	Transportable[g]
Acid Digestion	Y	B	P	N	Y	P
Adams Process Reaction with Sulfur	Y	B	P	Y	P	N
Catalytic Oxidation	Y	B	C	P	P	Y
Chemical Reagent Neutralization [a]	Y	P	C	Y	Y	Y
Direct, Fuel-Fired Combustion (Incineration)	Y	F	C	Y	Y	Y
Fixed-Bed Oxidation	Y	B	C	N	N	P
Fluidized-Bed Oxidation	N	—	C	Y	P	Y
Gas-Phase Chemical Reduction	Y	B	C	N	P	P
Hydrogenation Processes	N	—	C	N	P	N
Mediated Electrochemical Oxidation [a]	Y	P	C	Y	P	P
Molten Metal Catalytic Extraction	Y	B	P	P	P	N
Molten Salt Oxidation	Y	B	C	P	P	N
Plasma Arc Furnace [a]	N	—	C	P	P	P
Solvated Electron Reduction	Y	B	B	Y	P	Y
Steam Reformation [a]	N	—	C	P	P	Y
Supercritical Water Oxidation [a]	Y	B	C	P	P	Y
Wet Air Oxidation	N	—	C	P	P	P

[a] At least a part of the integrated system undergoing testing under the Assembled Chemical Weapons Assessment Program.

[b] Technology used to treat some type of chemical agent(s) in specific study. N = no; Y = yes.

[c] Development status of the technology. B = bench-scale; P = pilot-scale; F = full-scale.

[d] Development status of the technology. B = bench-scale; P = pilot-scale; C = commercial application.

[e] Technology used to treat some type(s) of energetic material. N = no; Y = yes; P = judged to be possible based on existing evidence that the feature shows promise, but has not been demonstrated.

[f] Technically capable of treating munitions casing or other contaminated material based on current stage of development. N = no; Y = yes; P = judged to be possible based on existing evidence that the feature shows promise, but has not been demonstrated.

[g] Suitability of technology for implementation in a transportable system based on current stage of development. N = no; Y = yes; P = judged to be possible based on existing evidence that the feature shows promise, but has not been demonstrated.

G.2 Challenges

Any alternative integrated system that used to treat non-stockpile CWM with an alternative treatment technology would have to overcome a number special challenges associated with the destruction of CWM. Some of the more difficult challenges are discussed below.

G.2.1 Chemical Warfare Material Variability

The system must be capable and versatile enough to process all expected CWM items in a variety of conditions. Non-stockpile CWM items are identified in Appendix B. CWM consist of items with various quantities and kinds of chemical fills existing in varying concentrations and in different solutions. Chemicals may be liquid, solid, or gaseous. CWM includes whole and partial items as well as loose component hardware. The CWM may be pristine or highly decomposed (see Appendix B). Internal and external dimensions may vary drastically for munitions of the same design. Excessive decomposition can weaken the structural integrity of the munition making the structure fragile so shock and vibration of munition during operations must be minimized.

Some of the chemical agents and industrial chemicals expected to be contained in non-stockpile CWM differ structurally more than those in the stockpile. The level of testing to date on chemical agents varies for each technology from gallons to grams. The majority of testing has been conducted using the most prevalent fill of chemical weapons: specifically sulfur mustard (H, HD), sarin (GB), VX, Lewisite (L), and a few of the industrial chemicals.

Much testing has been conducted on agent simulants since there are few facilities approved for testing with chemical agents. Most laboratory testing has only been performed using pure, or "neat" agent (no impurities). Non-stockpile chemical materiel (NSCM) agents will often contain various stabilizers and other additives, depending on the particular specifications during manufacture. Some chemical fills have different physical properties and contain arsenic compounds (for example, Lewisite and Adamsite). In addition, the long exposure to environmental conditions could have altered the chemical composition of some recovered items. It is very difficult to predict how well any technology would treat such material, especially the chemical treatment technologies.

G.2.2 Vapor and Explosion Containment

The system must be compatible with the operational safety requirements associated processing CWM. The greatest operational challenge is adapting a technology to work under the vapor and explosion containment protocols necessary for safe destruction of CWM. Pre-treatment accessing and treatment require vapor containment structures to prevent release of agent vapor. In addition, certain operations will require explosion containment.

In chemical demilitarization, containment refers to the ability of the process to contain vapors and/or explosions. Containment is a required safety feature, but seriously complicates

otherwise simple processes. As such, care must be taken when evaluating alternatives. Vapor containment is required for operating areas to control release of chemical fills. Accessing techniques for munitions with energetic components also require explosive containment. When vapor and explosion containment are combined, it is referred to as "total containment".

G.2.2.1 Vapor Containment

Vapor containment is a standard practice for many industrial chemical operations, but is more critical for chemical demilitarization. Conservative practice is to incorporate a cascaded ventilation system into the facility with activated carbon filtration on the heating, ventilation, and air conditioning (HVAC) system with a complex network of agent monitoring systems. The level of risk is determined from toxicology information, such as health hazard data, and defining acceptable time-weighted averages for exposure.

G.2.2.2 Explosion Containment

Explosively configured munition are rendered safe (the explosives are stable). Pre-treatment accessing requires explosion containment. Containment should be at the equipment level but containment at the facility level is acceptable. The goal is to minimize the extent of damage due to an inadvertent explosion.

Explosion containment is not limited to the brisance (i.e., the shockwave, overpressure, heat, etc., generated by an explosion). Explosion containment must account for all explosion consequences—the most damaging of which is flying debris from fragmentation (shrapnel). The difficulty is designing the structure to withstand repeated overpressures (brisance) as well as maintaining its integrity after fragmentation damage. Structures and equipment can and have been designed and tested to withstand inadvertent, and even periodic, fragmentation explosions. These vault-like structures are very heavy and seriously complicate transportability (even small ones), a requirement for non-stockpile CWM. In addition, small increases in structure size equate to large increases in weight. The challenge for alternative technologies is to fit into an explosion containment structure that is transportable and still allow for all aspects of operation, including personnel access for equipment maintenance.

Commercial transport devices are available that are reportedly able to withstand up to 55 pounds of trinitrotoluene (TNT)-equivalent explosive force, although total containment of gases in these devices is not likely. Vented Suppressive Shielding is a commercially available technology reportedly able to withstand up to 2,500 pounds of TNT-equivalent force for protection against an explosive fireball, blast overpressure, and fragments in a system comprised of a series of plates and screening. This system purposely vents pressurized gases during the explosion. A secondary containment structure, with a negative pressure that is maintained by an induced draft fan and filter system, may be able to afford protection from release of vaporized and particulate agent (Department of the Army, 1993).

Explosion Containment at the Facility Level. Reinforced concrete structures are routinely designed and fabricated to contain explosive brisance. Such structures will contain fragmentation but may do so at the loss of structural integrity and are not practical for a transportable system. Loss of any containment structure is unacceptable due to the difficulty of replacement. Metal explosion containment chambers are transportable. Brisance can be controlled by these chambers but fragmentation must be controlled by an inner layer of defense. Common practice is to install a sacrificial shield inside the blast structure. The shield must be designed to absorb or deflect fragmentation damage from the greatest explosion expected, protecting the outer pressure containing structure. Sacrificial shields provide protection only as a contingency. They are not intended for routine incidents. Sacrificial shields must usually be replaced after every explosion. In addition, unseen damage (such as stress cracks) places structures at risk.

Explosion Containment at the Equipment Level. The facility structure should be used to contain brisance but the equipment should be designed to minimize the effects of an explosion. Equipment can be made to resist brisance but like structural chambers, they are still susceptible to fragmentation damage. Containment of fragmentation at the equipment level minimizes the extent of the damage. Consider, for example, a thick metal pipe with end blast shields surrounding a projectile during a cutting operation. If an explosion occurred, the pipe would absorb or deflect radial fragmentation while the end blast shields would absorb or deflect longitudinal fragmentation. The pipe could be of single or concentric layers. An explosion would destroy only the pipe and the equipment immediately inside the device. The surrounding explosions containment chamber would provide the necessary vapor and brisance containment. The only containment alternative would result in destruction of the all equipment in the structure—the entire cutting mechanism, wiring, piping, transport equipment, etc.

Explosion Containment for Thermal Processes. Furnaces used for processing explosive feed (referred to as "pop furnaces"), must be explosion-rated[1] to contain over-pressure and fragmentation hazards. Refractory-lined furnaces cannot be fed material that can explode—the feed material must be pretreated to eliminate the explosive potential.

Fragmentation of any kind and brisance can damage refractory linings so care must be taken in process design to minimize overpressure, deflagration, explosions, and detonations. This is not limited to explosives processing. Consider, for example, accidental feeding of liquid in a sealed vessel to a furnace. The high temperature environment will cause the vessel to rupture creating overpressure and shrapnel. If the liquid is an organic, a combustion environment may cause rapid burning or deflagration of the liquid resulting in even higher overpressures.

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[1] Note: Explosion-proof is a misnomer. Equipment cannot be explosion-proof, only explosion-rated.

Since refractory cannot be used for processing materials that could explode (due to the inevitable damage), the operating temperature cannot exceed about 700-800°F (375-425°C) for carbon steel and up to about 335°F (850°C) for stainless steel. At high temperatures, most steel begins to exhibit metal fatigue and creep, resulting in significantly shortened life span and inadvertent failure. These are maximum temperatures; actual maximum temperatures are dependent on the equipment structure. Some complex assemblies may not properly function or may exhibit failure as much lower temperatures.

It must be noted that a temperature of 335°F (850°C) is not sufficient to eliminate reformation of complex and sometimes toxic products in some furnace systems, especially products of incomplete combustion. A temperature greater than 1,830°F (1,000°C) is necessary to ensure that complex hydrocarbons are eliminated. Further, there is no means to introduce air along the kiln length so starved air combustion and poor mixing results. Therefore, a refractory-lined afterburner is necessary after any explosion-proof thermal reactor.

Explosive feed material can be pretreated to remove its energetic potential. TNT has been slurried in water at a concentration of up to 25 percent explosive for thermal treatment in a fluidized bed furnace. Slurries with explosive chemical concentrations of 5 percent or less are safer. At this level of dilution, the explosive potential is eliminated. The challenge is separation of the explosives from the munition, size reduction of neat explosive, and maintaining homogenous slurries.

Contaminated equipment must be maintained by personnel is special personal protective equipment, which greatly complicates maintenance and necessitates that the equipment be simple and reliable.

G.2.3 Monitoring, Sampling, and Analysis

All chemical agent processes must be compatible with the chemical agent vapor monitoring systems used to detect agent vapor inside the facility. Typical incorporation of monitoring systems are discussed in Appendix C. Technologies must not generate any interference that may cause false positives or, more dangerously, false negatives (not indicating agent when agent is present).

All treatment processes must be capable of verifying chemical agent detoxification and, where applicable, explosives deactivation. Routine sampling and analysis of destruction is required using verified and validated test protocols or "methods". Development and validation of test methods is very difficult. Certain physical and chemical characteristics of a treatment waste stream could cause interference with test results and/or result in unacceptable detection limits (for example, only a capability of measuring to parts per thousand when parts per billion are required).

G.2.4 Development

Some of the aspects that would need to be considered in such a developmental effort are shown in Table G-6. As illustrated, certain basic conditions with respect to different types of non-stockpile CWM and site parameters would provide design criteria and performance specifications. Some of the resulting design and performance specifications would include the capability of the process to (1) treat non-stockpile CWM and handle waste streams, (2) measure and verify effectiveness, and (3) incorporate technological features that meet program needs for a dependable system. The system would also need to demonstrate that it could successfully address other factors regarding health and safety, regulatory requirements, and cost and schedule constraints.

G.2.5 Accessing

After the item is breached, the fill must be collected and fed to the treatment process. The method that is employed to accomplish this is dependent on the accessing method used to penetrate the casing or container, the treatment technology, and the characteristics of the chemical fill. For example, it may be necessary to dissolve gelled, partially solidified, or solidified fills using heat, water, steam, or reagents. If a treatment process is only capable of treating compounds in a gaseous state, liquid chemicals must first be evaporated before feeding to the treatment process.

Other challenges include the need to decontaminate the CWM item container and secondary wastes (those materials contaminated by the CWM during storage and processing) to assure proper and safe handling and disposal. The method used for decontamination of munition casings, bottles, and containers must be carefully integrated with the treatment process and accessing techniques since accessing processes may leave residual compounds in CWM items or change the physical or chemical composition of the fill. The subsequent steps to decontaminate the items would use methods that would not compromise the treatment technology.

In munitions containing explosive components, the explosives must also be properly treated or disposed. Acceptable technologies exist for the treatment and disposal of explosives. Some treatment technologies can process aqueous slurries containing explosive components which have been reduced in size and mixed with fluid to prepare the slurry. Many explosive compounds melt at moderate process temperatures, improving both access and reactivity. Aqueous solutions below their boiling point (usually near that of water at 100°C [212°F]) will melt many explosives. It must be noted that the technologies proposed for treating explosive components may or may not be compatible with the concurrent treatment of the chemical fill. An integration of the treatments of chemical fill, explosive components, and the post-treatment processes is a necessity.

Table G-7. Technology Development Factors

Basic Conditions	Design and Performance	Other Considerations
Non-Stockpile CWM Physical characteristics Wall thickness Metal type Dimensions Agent and explosive fill Amount Type Condition of munition Deterioration of casings Degradation of fill Number of items recovered **Site Parameters** Resources available Utilities - electricity, sewerage Water - potable/process Fuel - natural gas, etc. Land area - size, layout Access Rail Water Roads Airports	**Effectiveness** Health-based risk criteria Confirming Analytical Methodology **Size and Transportability** Physical dimensions Mobilization/demobilization Decontaminate process equipment **Technological Features** Assessment Complexity Containment Flexibility Reliability Equipment availability Operational capabilities Processing rate **CWM Component Processing** **Waste Management** Emissions Waste generation Waste disposal	**Health and Safety Concerns** Normal operations Off-design operations Monitoring/control requirements **Regulatory Issues** Permitting Compliance Air attainment classification Hazardous waste classification **Development Status/Maturity** Scale of operation - lab, pilot, etc. Agent testing Treatment of other non-stockpile CWM components **Cost and Schedule** Processing rate Manpower requirements

G.3 Pre-Treatment (Generic)

G.3.1 Overview

Pre-treatment involves preparation of material for the treatment operations and typically refers to an integrated process. An appropriate pre-treatment process must be effectively integrated with the specific treatment process. There are too many configurations and operating conditions used in industry (many are proprietary) to be able to specify all possibilities, so only generic applications are provided in this section. Many of the pre-treatment techniques are common industrial practices and are simply incorporated where needed. Such a variety of common operations does not require discussion, but one part of pre-treatment poses the greatest challenge to demilitarization—accessing. Accessing is a term used to describe techniques for gaining access to the chemical fills in the CWM. Once accessed, the chemical fills are typically removed. This can be as simple as letting a liquid chemical agent drain to more complex techniques of cleaning the hardware surfaces of all traces of chemicals. Once accessed, chemicals may be treated or repackaged. Accessing technologies are categorized into classes as described in Table G-8.

Table G-8. Pre-Treatment Accessing Classes

Class	Description
Cutting	Penetration or separation by means of a sharp instrument or by the physical removal, disturbance, or ripping of material.
Fragmenting	Fracturing of the material either into smaller pieces or by rupturing.
Separating	Disassembly, or reverse assembly, of components.

Accessing, like all operations, is accomplished in a controlled manner to minimize the associated risks. Accessing techniques for chemical fills in munitions with explosive components require that accessing does not initiate the explosive. Explosives have specific activation energies—the energy at which the explosive activates and may explode. Energy, or initiation stimuli, can be in the form of heat, friction, electrostatic discharge, impact, shock, etc., or a combination of these. Each of these stimuli can be mitigated, but it is preferable to select techniques that operate at conditions below the activation energy (inherently safe). For example, a saw blade generates too much heat and friction when dry so coolants and lubricants, such as water, are used to mitigate the initiation potential. An alternative approach would be to use fluid-abrasive cutting, which has been shown to have insufficient energy to initiate most explosives in use. However, due to the decomposed state of buried munition, the actual sensitivity of explosive compounds may be unknown. In addition, explosives migration within the munition, such as into threads, is also a possibility. Therefore, all applicable precautions should be incorporated to ensure minimum risk. Regardless of the accessing technology, all accessing processes will be subject to containment requirements—vapor containment for agent and explosion containment if explosives are present.

As mentioned, pre-treatment is an integrated process that may consist of multiple stages. One technique may be used to gain access to a chemical fill, others may be used to remove the chemical, and still another may be used to prepare the material for feed to the treatment process. This is demonstrated by the MMD process. The CWM is accessed by cutting a hole in the wall of the chemical agent reservoir. Most of the liquid agent drains naturally, but fluid spray washing is used to remove solid or gelled material from the reservoir.

Draining or evacuation of the chemical fill in munition or container reservoirs through small openings made by penetrating devices (for example, drills) does not allow the inside of these types of items to be completely exposed. Since fills may have gelled or hardened over time, accessing systems must also provide a capability for removing such materials to decontaminate the reservoirs. Once an item in an MMD is breached, pressurized spray systems allow for flushing out the reservoirs. Methods for removing the residual materials following draining include injecting pressurized air, water, steam, or specialized solutions to liquefy and mobilize the residual materials. The use of any solution to assist the removal of

residues in munitions or containers would need to be compatible with the treatment technology for the chemical fills.

Any accessing technique selected for development and incorporation into a treatment system would require careful system integration, testing, and evaluation of hazards. The following subsections discuss those accessing techniques that have been considered for both stockpile and non-stockpile CWM, which covers nearly all industrial, and some non-industrial, methods.

G.3.2 Cutting

Most common, industrial cutting techniques are listed and described in Table G-9. Some of these techniques are used for surfacing of materials rather than for the type of cutting necessary for accessing the chemical in the CWM, but are included for completeness. Cutting operations with a broader range of techniques, have experience with weapons, or were determined to warrant further explanation are discussed below.

Table G-9. Pre-Treatment Accessing: Cutting Techniques

Cutting Technique		Description
Chemical		Chemical machining (CHM) removes material by chemicals. (This process is normally only used for slow surface finishing by milling or blanking.)
Electrochemical		Electrochemical machining (ECM) or grinding (ECG) uses an electrolyte solution to dissolve material. (This process is typically for slow specialty cuts where material hardness and temperature are a factor.)
Electromagnetic Radiation		Laser-beam machining (LBM), Maser-beam machining (MBM), electron-beam machining (EBM) that melts, burns, or vaporizes material. (EBM must be conducted in a vacuum.)
Explosive		Use of shaped explosive charges that focus the detonation energy to blast a cut through the material. (Used in direct contact with the material to be cut.)
Fluid	Fluid-Jet	High-pressure fluid (liquid or gas) that erodes and deforms friable materials.
	Fluid-Abrasive	A fluid-jet (above) with entrained abrasive for cutting virtually any material.
	Fluid-Mining	A fluid-jet with special nozzles designed to rapidly remove or "mine" quantities of material in larger pieces (rather than precision cutting).
	Fluid-Spray	Lower pressure fluid-jet with special nozzles to clean surfaces.

Table G-9 (Concluded)

Cutting Technique		Description
Machining	Turning	Stationary single-, multiple, or rolling-point parting tools that chips or peals (involves shearing) material.
	Boring, Drilling, and Milling	Rotating metal shaft with single or multiple cutting tip(s) or an abrasive against a stationary, rotating, or axially moved item.
	Sawing	Rotating circular disk, rotating continuous metal band, or reciprocating linear blade with multiple teeth or abrasive (grinders) that cut or scrape material.
Shearing	Chopping	Metal blade, block-die, or plate forced through item.
	Punching	Metal punch or pinchers to puncture, pierce, perforate, rupture, or push through the item.
Thermal	Gas Flame	Oxygen and combustible gas to melt or burn material.
	Chemical Incendiary	Use of burning chemicals to melt or burn material.
	Plasma	Very high temperature corona of ionized gas developed from an electrical discharge.
Ultrasonic		Blade oscillated at high frequency and low amplitude to cut material (typically softer material like cloth, paper products, etc.). Ultrasonic machining (USM) uses a grit-impregnated blade to grind material (normally used for hard, brittle materials.)

G.3.2.1 Electromagnetic Radiation (Lasers)

The electromagnetic radiation directed in a highly intensified and focused beam of a laser can be used to burn, vaporize, or melt through munition casings or containers. It should be noted that the heat generated by cutting might cause decomposition of the chemical fills. Research is being conducted to reduce the amount of heat that radiates or conducts to the cut surface. Short-pulsed laser technology is currently being developed by the Lawrence Livermore National Laboratory to make extremely narrow and highly precise cuts in a variety of materials. Based on a demonstration of the laser cutting technology, cuts narrower than the width of a human hair can be made through thick material sections with no damage to the surrounding material. Specific applicability and use in chemical weapons demilitarization has not been fully demonstrated, though a production laser cutting system is currently being designed and constructed for use in other applications (LLNL, 1997).

G.3.2.2 Explosive (Shaped Charges)

Shaped explosive charges are simply explosives formed into special shapes that result in the focus of the detonation energy. Most of the explosives used are malleable and can be formed to nearly any shape. The explosives themselves are somewhat insensitive and must be initiated by a smaller detonating charge (e.g., a blasting cap). Shaped charges have been used for years for a variety of applications. A detonation shock wave moves faster than the

speed of sound and shatters metal. Properly configured, shaped charges form a relatively clean cut through metal. The charges are optimized to prevent incomplete cutting, but also to minimize excess explosive energy and shrapnel. It should be noted that the explosive energy might be enough to cause sympathetic detonation of other explosive charges in a weapon, but the risk is minimized if properly applied. Shaped explosive charges have been used for simple, quick access to chemical fills. Conical-shaped charges form holes in the munition body sidewall and flexible linear-shaped charges cut or section a munition. Shaped charges are used for accessing CWM in the EDS. In work conducted by the Canadian Department of National Defence, small penetrating charges were used to puncture non-explosive ordnance items containing aged and thickened mustard (McAndless, 1995).

G.3.2.3 Fluid (and Fluid-Abrasive)

High-pressure fluid can be used for a variety of accessing, size-reducing, and cleaning operations. The basic equipment set up involves a series of specialized pumps to achieve the required pressure. The fluid is channeled through piping to a nozzle, which is directed at the item to be cut by moving the nozzle of the item to be cut. The nozzle may be placed on a robotically controlled end effector and moved about the item to be cut, or the nozzle may be fixed and the item to be cut may be moved.

There are no standardized, adjectival descriptions for fluid pressure, but the ranges shown in Table G-10, below, are used in this document.

Line pressure represents the pressure of normal fluid lines throughout an operation (such as a faucet). Low pressure represents a pressurized fluid common in industrial practices, such as a deck washer. The medium, high, and ultra-high pressure level represent operations that require equipment that is more specialized.

Table G-10. Pressurized Fluid Designations

Designation	Pressure Range (bar)
Line Pressure	<10
Low Pressure (LP)	10–100
Medium Pressure (MP)	100–500
High Pressure (HP)	500–1,000
Ultra-High Pressure (UHP)	>1,000

1 bar = 14.5 pounds per square inch 1 atmosphere

Fluid systems introduce notable additional material to the material being cut—specifically fluid and, when used, abrasive. Fluids and abrasives have been used that evaporate after use (e.g., ammonia, as a fluid, and carbon dioxide "dry ice" pellets from grit blasting). However, water is the most common fluid and garnet is the most common abrasive. Aqueous chemical reagents are also used. It should still be noted that any cutting media requires treatment to destroy any agent or explosives contamination.

These systems have been optimized by commercial industry over the last decade to improve performance. Once selected, the system is further optimized to maximize cut efficiency (maximum speed with minimum fluid and abrasive waste).

Fluid-Jet and Fluid-Abrasive

Pressurized fluid cuts, or erodes, swarf from material to form a kerf. Fluid alone, or "fluid-jet cutting", cuts a variety of friable materials, but the incorporation of abrasive into the fluid stream ("fluid-abrasive cutting") allows virtually any material to be cut. The abrasive may be entrained in any fluid or gas. When entrained in a gas it is referred to as "grit blasting", and is routinely used to clean surfaces of debris. Most liquid systems typically operate in the ultra-high pressure range; some systems operate down to the medium pressure range (typically with a greater quantity of water and abrasive). Gas systems tend to operate at or below the low-pressure range.

Fluid-Mining

Fluid mining uses high-pressure fluid to cut and remove friable solids from metal structures. The force of the water cuts and breaks the solid while flushing the size-reduced material from the structure (literally "blowing" or cutting solids from the structure). Its application to demilitarization is for removal of agents and explosives.

The process is very similar to fluid-jet cutting (no abrasive), but uses a broader range of fluid pressures. Pressures range up to the ultra-high pressure range, but the medium pressure range is most popular commercially. Fluid mining also incorporates special nozzles that allow mining rather than precision cutting.

Fluid-Spraying

Fluid spraying uses high-pressure fluids to wash surfaces or remove debris similar to fluid mining, but at a lower pressure and using nozzles that typically form a fan spray rather than focused streams. These systems are very common in industry and have been developed for cleaning chemical agent and debris from CWM.

G.3.2.4 Machining

Machining refers to using a tool with one or more cutting blades to remove material (swarf) to form a kerf (the width of the cut). Machining includes all common industrial turning, drilling, boring, sawing, milling, etc. With proper tool configuration, any material

can be machined. The material to be machined is secured into a device that may hold it in place or may maneuver it (e.g., rotate, slide, lift, etc. or a combination of these). The cutting tool is installed into a holder, or "jig". The tool and/or the material to be cut are moved and the contact of the two forms the cut. Types of machining applicable to pre-treatment accessing are discussed below.

Drilling, Boring, and Milling

Drilling and boring are the same for this application—a rotating cutting tool is pushed through a stationary piece to cut a hole. The only difference is that a drill bit is a fluted rod with cutting blades at one end and a boring bit is a tool with replaceable cutting blades attached to the end. For CWM, the hole provides access to the interior. Liquids can be drained and solids can be washed out.

Remotely operated drilling and boring have been used to safely access both the chemical and explosive components in various CWM items. The drill and transfer system was originally designed by the Army for transferring chemical agent from unserviceable munitions to interim storage containers for subsequent reuse or disposal. The drill and transfer system included a glovebox into which the munition was loaded and positioned under a remotely operated drill. Once access holes were drilled, a sample taken for identification and then a suction tube was placed in one of the holes to transfer the agent to a storage container. The munition was then decontaminated by a decontaminating solution, which was also pumped to a holding tank for follow-on processing or disposal (Department of the Army, 1993).

Another drilling method based on the oil industry method of "hot tapping" into operational oil and gas pipelines has been developed and patented for accessing the contents of CWM. This technology, which is currently under development in the United Kingdom, seals a special tool onto a munition casing and drills a hole inside the vapor seal. The tool contains pipes and valves that allow the contents of the munition to be evacuated from the munition body and then flushed and decontaminated (NATO, 1996).

Sawing

Saws may consist of a circulating, rotating, or oscillating fixture with multiple cutting blades. Conventional circular saws operate at relatively high speeds and may generate too much heat to be applicable to explosively configured munitions. Another type of cutting device, the diamond wire saw, typically used to cut through concrete could also be used for accessing CWM items.

Slow-moving band saws (that is, those operating at 30 to 120 revolutions per minute) have been successfully used on munitions with explosive components at Picatinny Arsenal, New Jersey. These types of saws are primarily used for metal cutting and are available in a variety of sizes. Circular carbide-tipped milling cutters can also cut metal effectively at low speeds without excessive heat or spark generation. Reciprocating saws that move back and

forth can also be precisely controlled to regulate heat generation and the amount of cut material. Saw blades impregnated with small particles (grit) and shaken or oscillated at a very high frequency have been used to grind slots into hard substances.

G.3.2.5 Shearing

Shearing, unlike machining, cuts by deforming the item using sharp blades, pointed implements, block-dies, or plates without the intentional removal of material. Shearing includes all common industrial punching, chopping, slicing, shredding, crushing, etc. Shearing is somewhat dependent on the thickness and type of material. The cutting tool is usually forced through the item using a hydraulic press, the thicker the material the more force required. Shearing can be used for accessing thick-walled items by punching or thin-walled items by slicing (like scissors). Chopping and shredding provide size reduction. The Army routinely uses a hydraulically actuated system to access M55 rockets—a punch (followed by vacuum drain) for the agent reservoir and a guillotine shear for sectioning into shorter pieces (Department of the Army, 1993).

G.3.2.6 Thermal

Thermal cutting produces high temperatures and releases sufficient heat to cause decomposition of the chemical in the CWM. For this reason, thermal accessing techniques are often considered "one step" methods. It should be noted that the thermal decomposition of the chemicals occurs, but is not necessarily provide complete detoxification of chemical agents (further treatment required).

Chemical Incendiary

Certain chemicals produce very high temperatures 4,500°F (2,500°C) and large quantities of heat when ignited. The most notable is thermite, a mixture of powdered or granular aluminum metal and powdered iron oxide. Thermite reacts violently (almost explosively) so is only used in moderate quantities. Shaped charges are used to burn through the sidewalls of munitions.

Plasma

Plasma is ionized gas generated during the discharge of electricity, much like with lightning. When controlled in a continuous manner, this corona of ionized gas can generate temperatures high enough to melt many materials. There are three basic types.

- Coupled Arc: Corona forms between an electrode directly to the item being cut, which acts as the other electrode (arc welding).
- Non-Coupled Arc: Corona forms between two electrodes at the end of a torch. Gas is injected through the torch to disperse the corona over a larger area.
- Submerged: Electrical or electrostatic discharge machining or grinding that uses spark erosion to remove material while submerged in a dielectric fluid. (This process is normally only used for slow, precision cuts. with the fluid providing cooling.)

G.3.3 Fragmentation

Fragmentation is the fracturing of the material either into smaller pieces or by rupturing.

G.3.3.1 Cryogenic Embrittlement

Cryogenic embrittlement is the process of breaking, or fracturing, materials that have been cooled to temperatures that cause them to be very brittle. This produces pieces or fragments of a munition casing or container, as well as pieces of the internal chemicals and explosives. The item to be frozen is immersed in a bath of cryogenic fluid such as liquid nitrogen. Once frozen to the point where the material becomes brittle, a physical force is imparted causing fragmentation. The physical force may be a press, hammer, or crushing rollers. This technique is most applicable to whole CWM items, but may be adaptable to other feeds. The fragmented pieces should be compatible with a variety of treatment technologies.

The extensively demonstrated cryo-fracture as an alternative to separation (reverse assembly) of the chemical weapons stockpile. This system consisted of a dip tank with liquid nitrogen, a hydraulic press with fracturing dies, and robotic systems to move the munitions between the units (Department of the Army, 1987). The Army's cryo-fracture system was demonstrated on hundreds of items including artillery shells, mortar shells, rockets, and landmines (Department of the Army, 1995).

G.3.3.2 Controlled Detonation

Controlled detonation uses heat or supplemental explosives to access the chemical fill. Controlled blast charges are also used in some circumstances by explosive ordnance disposal teams to propel small penetrating projectiles through casings to expose and in some instances, vent the fill.

Explosive Supplemented

Explosive supplemented, controlled detonation uses explosives to, at a minimum, access the chemical fill, and, in the extreme, to completely destroy the item.

Explosives may also be used to destroy the item using above ground or underground methods. Contained detonation technologies use the energy released from a detonation to simultaneously access the munition, destroy the explosive fills and, to some extent, destroy the agent fills. Supplementary explosives are used to enhance the destructive force. Detonation processes surround munitions with sufficient supplementary explosive charges for optimum destruction with minimal excess. Supplemental thermal charges may also be used to enhance the thermal destructive capabilities.

All approaches are designed to withstand and contain the brisance and shrapnel generated by the largest explosive event possible. Significant explosion containment, above or below ground, is incorporated for the resulting blast. Aboveground structures ("detonation chambers") are airtight structures that continuously vent the gases to the next step in the

process and periodically transport shrapnel. Underground detonation configures munitions, explosives, and thermal charges underground using blast containment strategies that incorporate sand, small stone, earth, and other media. After detonation, the blast containment media is collected for remediation.

Thermally Initiated

Thermally initiated, controlled detonation technologies use heat to cause explosive components to decompose and sometimes explode inside a thick-walled, explosion-rated furnace. The capability of a metal structure to withstand high temperatures and detonations are limited. These systems typically operate at lower temperatures than agent destruction furnaces. They are not fed whole munitions to minimize deterioration of the furnace interior, only explosive components or explosives that have been reduced in size. There are a number of furnace technologies, discussed in Section G.4, which fit these basic design characteristics.

G.4 Treatment (Generic)

This section generically discusses treatment techniques. Treatment technologies are categories as thermal or chemical due to the significant differences in the equipment and operations involved. Thermal treatments commonly have a reactor (furnace) with a heat source and a gaseous reactive environment. Chemical treatments commonly have a mixing or agitating reactor and one or more liquid chemical reagents. Two other treatment categories, biological and irradiation, are also included.

G.4.1 Treatment Terms

In order to enhance the understanding of the various treatment technologies described in Section G.6, some of the terms that are used in the descriptions are briefly defined below.

- **Catalyst**—A substance or combination of substances that accelerates a chemical reaction without itself being permanently consumed (Metcalfe et al., 1986).
- **Fluidized Bed**—A bed of small solid particles suspended and kept in motion by an upward flow of a gas (Merriam-Webster, 1995).
- **Hydrogenation**—A chemical change in which hydrogen is combined with some other substance (Dorin, 1987).
- **Incineration**—A treatment technology involving destruction of waste by controlled burning at high temperatures (for example, burning sludge to remove the water and reduce the remaining residues to a safe, non-burnable ash that can be disposed of safely on land, in some waters, or in underground locations) (EPA, 1994).
- **Neutralization**—A process sometimes called chemical hydrolysis wherein an acidic substance such as a chemical agent is reacted with an aqueous basic substance that results in products of reduced toxicity (NRC, 1994).

- **Oxidation**—The addition of oxygen that breaks down organic waste or chemicals such as cyanides, phenols, and organic sulfur compounds by bacterial or chemical means (EPA, 1994).
- **Oxidative State (Number)**—The number of electrons that have been removed from, or added to an atom when it forms a compound. The oxidative state of an element is usually equal to the charge on the ion. An element's oxidation state increases when oxidized and decreases when reduced (Wertheim et al., 1987).
- **Oxidizing Agent**—A substance that provides oxygen, loses hydrogen, or gains electrons in its reaction with another substance (Wertheim et al., 1987).
- **Plasma**—A gas at very high temperature in which the constituent molecules have dissociated into ions. This makes the plasma electrically neutral overall but a good conductor of electricity (World Book, 1984).
- **Reduction**—A chemical reaction in which one of the following occurs: (1) a compound loses oxygen, (2) a compound or element gains hydrogen, or (3) an atom or ion gains electrons (Wertheim et al., 1987).
- **Supercritical Water**—Water that has been subjected to moderate temperatures of 842 to 1,112°F (450 to 600°C) and high pressures of approximately 3,500 pounds per square inch (246 kilograms per square centimeter) that has characteristics that enhance the breakdown of large toxic organic molecules into smaller, less toxic molecules with an oxidizing agent (Department of the Army, 1994).

G.4.2 Thermal Treatment

This section discusses thermal treatment processes (furnaces). Due to the common heating methods and reactive environments of furnaces, this section provides a generic discussion of furnaces. This is followed by specific discussions of furnaces that are commonly available. Thermal treatment operations detoxify chemical agents and deactivate explosive materials using heat, also called "thermolysis". Thermal treatment is accomplished by initiating a reaction under high temperature conditions. The heat alone can and does destroy the chemicals but the reactive environment inside the furnace defines the reaction products.

G.4.2.1 General Furnace Attributes

Three distinctive features are used in this appendix to categorize furnaces: the heating method, the equipment configuration, and the reactive environment.

Furnace Heating Methods

Heating of thermal treatment processes may be direct, indirect, or a combination of these. Heating may also be staged, using one method to preheat and another to maintain heat during processing. The most common methods are fuel-fired, radiation (electric), plasma arc (torches and electrodes), and induction systems. Indirect heating provides only heat to the

interior of the reactor. Direct heating of the reactor interior has varying effects on the reactive environment.

Direct, Fuel-Fired (Combustion). Direct, fuel-fired combustion (incineration) dictates a reactive oxidative atmosphere. These systems typically operate with 7% excess air to improve combustion and reduce the hazardous products of incomplete combustion (PICs). Indirect fuel-fired combustion is simply a heating shroud around the reactor. Many fuel-fired systems are capable of using multiple fuels such as natural gas, propane, or a number or petroleum-based fuels.

Plasma. Plasma can be formed by an electric arc torch, an electrode, or it can be radio frequency generated (induction coupled/electrodeless). These systems may be coupled or non-coupled. Coupled systems form an arc from the torch or electrode to a contact in the bottom of the reactor. Non-coupled torches are not the same as simple electrodes in that the plasma arcs across the tip of the torch. These systems blow a low-pressure stream of gas through the arc to form a corona of ionized gas. Radio frequency generated systems have had little use. The ionized gas produced by plasma arc torches and electrodes causes dissociation of chemicals into their elemental states, allowing the resulting environment to better reform the products. In the plasma arc furnace, a feed stream is exposed to ionized gas (reaching temperatures of 6,000-20,000°C [11,000-36,000°F]) in a furnace. The reactor operates at temperatures from 1,400-1,750°C and near atmospheric pressure. The gas flow rates are much smaller than direct, fuel-fired combustion systems, but are fed to the same, standard emissions control system (only much smaller). Plasma arc systems have short start-up times, have shown effective thermal destruction capabilities on a variety of hazardous materials, and have efficient throughput rates with comparably lower operating costs.

Radiation (Electric). Radiation heating, also known as infrared heating, uses infrared waves emitted by simple electric elements to achieve temperatures up to 1,800°F (1,000°C). Infrared incineration has been successfully used in numerous environmental remediation projects for the past seventeen years. It appears that destruction of polychlorinated biphenyls (PCBs) is the most common and proven usage of radiative heating. Use of radiative heating has progressed towards thermal or indirect adsorption where no destruction of volatized hydrocarbons takes place. Instead, the stripped hydrocarbons are pyrolyzed in a reduced atmosphere (<3% O_2) and condensed/recovered downstream in a quenching/cooling system. Electric heating produces minimal gas emissions, somewhat less than a plasma arc torch. Like plasma systems, they have relatively short start-up times, have shown effective thermal destruction capabilities over a wide variety of hazardous materials, and have efficient throughput rates with comparably lower operating costs.

Induction. Induction uses an alternating magnetic field to electrically heat conductive material up to 5,400°F (3,000°C). It is most often used to maintain the temperature of a molten media.

Furnace Configurations

There is a variety of furnace designs applicable to demilitarization operations. Descriptions are available in many technical handbooks under "Drying Equipment". This section only discusses the some types of furnaces and related equipment used in the industry. In this appendix, furnaces are any heated chambers used to process material. They may be refractory lined or not, may be stationary structures or rotating cylinders, and/or may have molten pools.

Refractory linings are required for operating temperatures above about 1,500°F (850°C). As the temperature increase, steel begins to exhibit metal fatigue and creep, resulting in mechanical failure. As discussed earlier, explosion-rated furnaces cannot have refractory, thus cannot exceed about 1,500°F. However, a temperature of 1,500°F is not sufficient to eliminate reformation of complex and sometimes toxic products in some furnace systems, especially products of incomplete combustion. A temperature greater than 1,800°F (1,000°C) is necessary to ensure that complex hydrocarbons are eliminated. Therefore, a refractory-lined afterburner is necessary after any explosion-proof thermal reactor. The following represent some common types of furnace equipment configurations used in industry.

- *Fixed Bed.* This is a stationary bed of media that can be inert (e.g., glass, ceramic, etc.), reactive (e.g., alkaline), or a catalyst (e.g., nickel, iron, etc.).
- *Fluidized Bed.* This is a bed of granular solid media with an up-flow of gas through the media to fluidize it. Media can be an inert catalyst (e.g., glass, ceramic, etc.) or reactive (e.g., alkaline).
- *Molten Media.* Molten media furnaces use a molten pool (e.g., glass, metal, ceramic, salt, etc.) to treat feeds. The feed is often injected directly into the media.
- *Static.* The basic static, or stationary, hearth furnace is a simple heated chamber or vessel with no materials transfer methods. Gas, liquid, or solid materials are fed directly into the furnace and heat is applied to destroy the feed.
- *Rotary.* Rotary furnaces have a rotating vessel that may be refractory lined. When a helical flight, or "retort", may be used to transport material through the furnace (a "rotary retort").
- *Tunnel.* Tunnel furnaces are static furnaces where material is loaded into it or through it using a number of common, industrial, materials transfer methods. Some of the more common used for demilitarization are roller conveyors, chain conveyor, and roller hearths.

The basic configuration of most furnaces is similar, consisting of a metal support structure, refractory-lining (when applicable), a heat source, feed and exhaust ports, and associated monitoring and controls systems. A basic furnace is shown in Figure G-1.

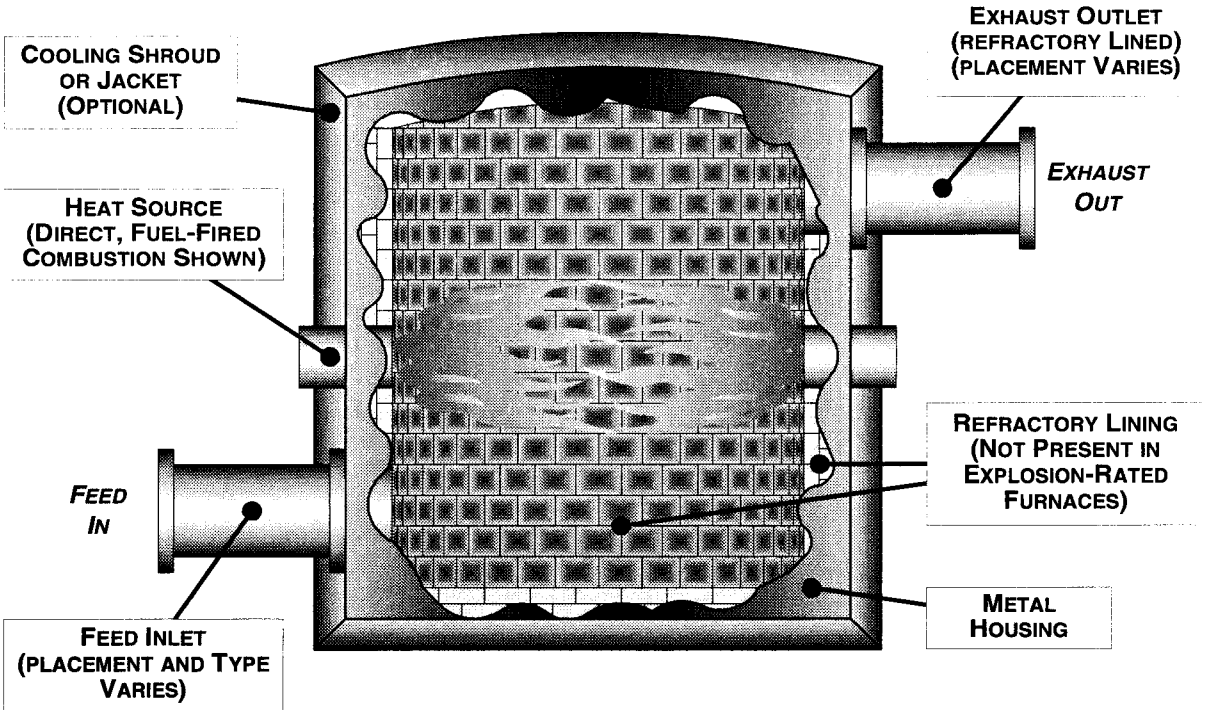

Figure G-1. Basic Furnace Equipment Features

Furnace Reactive Environment

The basic reactive environments are as follows.

- Thermal Oxidation—Heat in an oxygen rich atmosphere
- Thermal Reduction—Heat in a hydrogen rich atmosphere (hydrogenolysis)
- Thermal Hydrolysis—Heat in the presence of water (steam)
- Thermal Reaction with Sulfur—Heat in the presence of elemental sulfur

Sometimes reactions are claimed to be pyrolysis. Pyrolysis breaks chemical structures down into simpler structures using heat alone. 'Pure', heat-only pyrolysis is difficult to achieve in CWM destruction since molecules of hydrogen, oxygen, and halogens (for some chemical fills and decontamination solutions) are present in the feed. In addition, pure pyrolysis typically produces carbonous residue and particulates that foul the furnaces, the transport mechanism, and the downstream processes. Although the heat may cause pyrolysis of a chemical the resulting, decomposition products react with the environment of the furnace to form new products.

G.4.3 Chemical Treatment

Chemical treatment involves the addition of reagents to change a chemical's structure. Neutralization is the detoxification or reduction in toxicity of chemical substances using reagents. Some chemical treatment technologies may neutralize chemical agents, but may produce other chemical substances that are toxic nonetheless. Sometimes the temperature and pressure conditions are varied to improve reactivity or drive the reaction toward certain products. The types of chemical treatments are vast—there are too many possible chemical reactions and not all can be described.

Chemical treatments use common commercial equipment. Chemical treatment reactors must thoroughly mix the feed and reagent for a specified duration to ensure complete reaction. Reactors are typically jacketed to maintain operating temperature and may be vented to maintain operating pressure. The process can consist of a single reactor or of multiple reactors in series. Common reactors include mixers (inline static or stirred tank), tumblers (dual cone, helical, etc.), or any other equipment that agitates the feed and reagents.

The reagent can be one or more chemical compounds and can be added simultaneously or incrementally to achieve the desired reactions. Alternately, the agents or explosives can be added incrementally to the reagents. Liquids are typically sampled to verify reaction completeness before release to post-treatment. Offgas is treated to ensure cleanliness before release from the toxic area. Solids decontaminated by chemical reagent treatments are not considered completely free of chemical agents or explosives but can be considered safe enough for a landfill.

Chemical treatments can use whatever reagent is shown most effective. Some systems can be changed over to other reagents using the same equipment. Liquid treatments allow "hold-and-test" protocols provided the resulting waste stream does not contain components that interfere with monitoring methods. The liquid waste can usually be sampled for verification of destruction effectiveness prior to releasing the liquid for post-treatment.

The products resulting from chemical neutralization reactions vary. They can range from being mostly one chemical to being a complex combination of chemical by-products and isomers due to chemical affinities and side reactions. The reaction chemistry and kinetics can be difficult and can be effected by impurities. The quantitative goal is mostly to identify every final chemical constituent of the neutralized product to help facilitate a secondary post-treatment operation for the waste steam. For the most part, the stronger the reagent the more complete the main reaction.

Containment and recovery of arsenic from chemical processes is somewhat easier than for thermal treatment processes (furnaces) where the arsenic must be captured from a gaseous stream. Feed rates and temperature control are critical to ensure proper reaction and to prevent reaction exotherms.

G.4.3.1 Chemical Hydrolysis

Hydrolysis increases the proportion of OH in a compound. This typically involves cleaving the molecule to add the hydroxy radical (OH^-). Hydrolysis can be accomplished by a variety of reagents with the OH molecule including water (H_2O), sodium hydroxide (NaOH), etc.

G.4.3.1 Chemical Oxidation

Chemical oxidation can occur under normal processing conditions (temperature and pressure). It can also be accelerated by using ionic solutions (electrochemical) or by ultraviolet (UV) light (photochemical). Strong oxidizing reagents demonstrated to successfully oxidize CW agents at or near ambient temperatures include peroxydisulfate salts, organic peroxides, chlorine dioxide, hydrogen peroxide, chlorine (in an acid solution), and ozone. Finely divided metal oxides have been shown to catalyze the destruction of CW agent simulants by oxygen and peroxide. There is a variety of strong oxidizing reagents that are commercially available. Some candidates are peroxydisulfate salts, OXONE®, organic peroxides, chlorine dioxide, hydrogen peroxide, chlorine (in an acid solution), and ozone which have all completely oxidized CW agents at or near ambient temperatures.

Mediated Electrochemical Oxidation

Electrochemical treatment uses strong, electrically generated chemical reducing/oxidizing (redox) ions, or mediators, to destroy or synthesize organic substances. Some mediators are powerful enough for chemical destruction while others are typically only used for organic synthesis. Electrochemical treatment has demonstrated successful destruction of a variety of organic substances and treatment of many metallic materials. This treatment uses an electrolytic cell to generate the mediators. The organic substance is fed to water or an aqueous electrolyte solution (e.g., acids like nitric or sulfuric) where a redox ion, or mediator, is continuously produced by the anode of the electrolytic cell. The mediator reacts with the organic substance and is reduced but stays in the electrolyte and can be regenerated by the anode. The ions may react directly to destroy an organic material or may first react with water to form hydroxyl radicals that, in turn, oxidize the material.

Electrochemical oxidation, the more common reaction, produces waste streams that consist of basic oxidation products (gaseous carbon and nitrogen oxides) and sulfates, phosphates and phosphorus pentoxide, nitrates, and chlorides depending on the feed components.

G.4.3.1 Photochemical Treatment

Photochemical treatment is the combination of light and reagents to neutralize toxic chemicals. The light acts as a catalyst by increasing the Activity State of the reagents resulting in faster chemical attack and destruction of the toxic chemical substances. This is also referred to as photolysis. The typical process is conducted at ambient temperature and pressure by pumping the diluted chemical solution through clear pipes surrounded by the light source. Exposure to the light is necessary for proper activation of the reagents. Slurries or nontransparent feeds are more difficult to process since they prevent light penetration.

G.4.4 Biological Treatment

Biological treatment is a specialty technology and must usually be tailored for specific chemicals. Biological treatment is accomplished by degradation (biodegradation) of the chemical by living organisms or by enzymes. Biological organisms (microbes, bacteria, fungi, algae, microflora, etc., casually referred to a 'bugs') can degrade a molecule if it resembles the organism's enzyme pathway. Biological organisms may be evolved through genetic manipulation (or 'cultured') to digest chemicals due to their short life span and adaptability. Certain enzymes have also demonstrated the capability of decomposing chemicals. Ideally, biological treatments are designed to decompose chemicals into environmentally friendly compounds but they may only detoxify chemicals into other compounds. Currently, biological technologies have only been applied to post-treatment of waste from chemical reagent neutralization.

G.4.5 Irradiation Treatment

Irradiation uses only penetrating radiation or light to decompose chemical substances. This is very similar to photochemical treatment discussed above but without reagents. This treatment will only work if the chemical substances undergo decomposition by some form of radiation. This process is also subject to the same conditions as photochemical when light is used. Radiation penetrates substrates so transparency is not as much an issue. Gamma radiation initiates chemical syntheses and crosslinking but does not completely destroy chemical agent. Penetrating radiation could possibly accelerate partial decomposition of the munition contents, but may only achieve pre-treatment. Additional treatment (with destruction verification) and post-treatment may still be required. It should be noted that gamma rays are very penetrating and exposure can be lethal, so complete protection is essential.

G.5 Post-Treatment (Generic)

Post-treatment operations are those that change the chemical nature of a waste stream to remove its hazardous characteristics. Streams from post-treatment are subject to an effluent management strategy where physical reconfiguration may take place (e.g., containerization, evaporation, etc.).

Post-treatment would likely involve processes designed primarily to meet regulatory disposal standards. Selection of the appropriate process to complete treatment would depend on the by-products produced, and decisions regarding potential recycling or reclamation. For example, the process may incorporate heat recovery systems that may be used in the overall processing scheme, or may incorporate recovery of metals or useful by-product gases. Recycling would also be advantageous in that process efficiencies could be increased and lesser amounts of undesirable effluent would result. Post-treatment processes that may meet development needs are numerous and include: volatile organic stripping; acid gas scrubbing systems; liquid stream conditioning (for example, pH control and degasification); particle

filtration; biodegradation; treatment with ultra-violet or infrared energy; chemical reagent oxidation; carbon or selective-ion absorption or adsorption; gravity separation; stabilization; ion exchange; vitrification; and membrane separation. These and other standard processes may also be combined with one other in a sequential operation.

Some post-treatment operations could use several of the technologies described. However, many developers and vendors of specific treatment technologies utilize post-treatment processes that are designed specifically to work with their process. In many cases, this may involve recycling certain by-products, or recovering materials that may have value. It is always desirable to reduce the amount of waste that must be handled and disposed.

G.6 Commercial Treatment Technologies

This section discusses several existing technologies that may be capable of treating chemical fills in non-stockpile CWM or the neutralent generated from the transportable chemical treatment systems. Any treatment process considered for the treatment of non-stockpile CWM containing chemical agent must be fully integrated into a system that is capable of meeting the challenges outlined earlier in this chapter. Further research and development is required in order to design and build such a system, including adequate testing to ensure that safety and treatment standards can be met.

Technologies with the potential to treat the weapons, both chemical and conventional, continue to be examined by a variety of international groups. More recently, developers and vendors of technologies that may be capable of treating the stockpile of assembled chemical weapons have been solicited by the Army to participate in a cooperative effort with citizens groups and various government agencies to develop at least two alternative systems to the baseline incineration process. The technologies presented in this section include many that have been examined for treatment of the chemical stockpiles, may be capable of treating non-stockpile CWM, or may be capable of treating the neutralent generated by the transportable chemical treatment systems.

The technology descriptions, which are categorized by thermal and chemical in the following subsections, are based on publicly available sources of information. The information presented is intended to provide the reader with a basic understanding of each of the treatment technologies. Each discussion includes the following:

- A brief overview of each technology, summarizing distinguishing highlights
- A short description of the physical and process features, including a diagram depicting the process and major system components, process flows, and waste streams
- A brief discussion of the development and potential applicability of each of the treatment technologies to the treatment of non-stockpile CWM, including whether or not the technologies may be capable of treating non-stockpile CWM components other than chemical agents (that is, explosive components or munition-body metal

parts) Whether or not a process is able to treat these other components would need to be tested and evaluated by the Army.

Each treatment technology described in the following subsections generates a unique process stream, waste effluents, or emissions that require further treatment. For example, processes that produce acid gases require emissions controls (e.g., scrubber) to minimize the release of acids to the atmosphere.

G.6.1 Thermal

G.6.1.1 Adams Process (Reaction with Sulfur)

The Adams process is a furnace that uses sulfur in an oxygen deficient reactive environment.

Overview

In the Adams process (Figure G-2), chemical agent as a liquid or gas is heated in a furnace with sulfur in a reduced oxygen environment at ambient pressure. The gases entering and exiting are carefully controlled. An oxygen-free gas (such as nitrogen) is used to maintain the reduced oxygen environment.

The ability to treat some chemical agents and explosive compounds in the laboratory has been demonstrated, and treatment of some industrial waste compounds has been successfully completed during small-scale pilot testing. The process has been studied using several different size reaction vessels, batches, and configurations that indicate the possibility that the process could be incorporated into a system that is mobile and may be flexible enough to handle various types and sizes of materials to be treated. The chemistry of the Adams process is not fully developed, so the amounts and kinds of process by-products need to be determined in detail. Early testing indicates that most of the treated material is incorporated into a stable solid. Other waste products can be treated using technologies currently available or practiced in more traditional industrial operations.

Description

The Adams sulfur process utilizes the reactivity of elemental sulfur, either in a vapor-phase or in liquid-phase, to treat organic materials in the absence of oxygen. The liquid-phase reaction is carried out at temperatures ranging from 275 to 850°F (135 to 454°C) under normal atmospheric pressure conditions. Higher temperatures (those approaching 1,800°F [1,000°C]) have reportedly been used when running the reaction using vapor-phase sulfur (NATO, 1996).

The basic process is depicted in the flow diagram, Figure G-3. As illustrated, organic compounds such as chemical agent in liquid, gas, or solid form are combined with liquefied or vaporized sulfur, and fed into a reactor where they are heated in an oxygen deficient

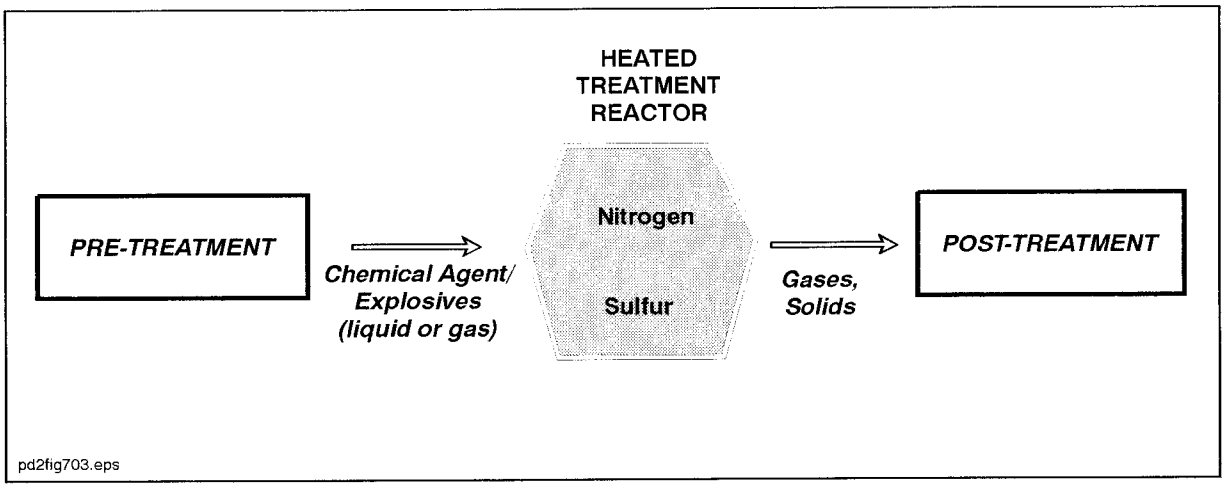

Figure G-2. Illustrative Diagram of Adams Reaction with Sulfur

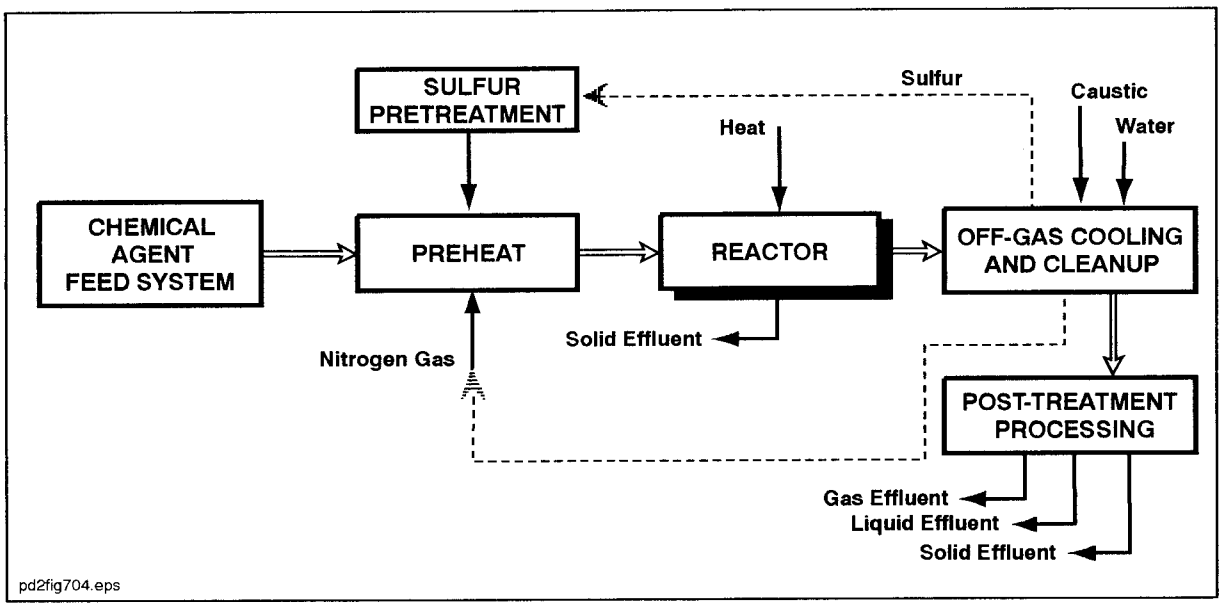

Figure G-3. Process Flow Schematic for Adams Process Reaction with Sulfur

atmosphere. The oxygen deficient atmosphere is created by purging the reactor with nitrogen gas at slightly above atmospheric pressure to prevent air infiltration. The treatment reactions are expected to occur fairly rapidly and produce a black glassy product (that is, a polymeric form of carbon-sulfur), very fine dust particles, and off-gases that include nitrogen and unreacted sulfur vapors such as carbon disulfide, hydrogen sulfide, carbonyl sulfide, sulfur chloride, thionyl chloride, and hydrogen chloride. The off-gases are then passed to a tempering step where they are cooled, generating a condensate that is expected to contain sulfur, carbon disulfide, and sulfur chloride. Following the tempering step, the off-gases are then passed through a cyclone to remove entrained solids and a wet-scrubber, or alkaline media, for acidic gas removal. Any resulting brine is separated from the effluent gases and treated appropriately. It is expected that the nitrogen gas is isolated and returned to the process (Department of the Army, 1994).

For chemical agents, reactions in molten sulfur or sulfur vapors are somewhat analogous to thermal oxidative reactions however the reactions produce different by-products. Examples of by-products from the sulfur process reactions involving chemical agents would include hydrogen sulfide, sulfur dioxide, carbon disulfide, hydrogen chloride, and/or nitrogen oxides, phosphorous sulfides, and sulfur chlorides and fluorides. The particular by-products and relative amounts are dependant on actual process conditions and the type of agent being processed. It is not known what effects, if any, the reactions with chemical agents may have on the residual carbon-sulfur solid (NRC, 1993).

Development and Applicability

Bench-top and pilot-scale experimentation at the University of Pittsburgh have indicated that the Adams process is capable of treating a variety of organic and chlorinated compounds without the production of chlorinated dioxins (NRC, 1993). At an open conference sponsored by the U.S. Army Assembled Chemical Weapons Assessment Program in June 1997, Sultech, Inc., and the University of Pittsburgh Applied Research Center reported that testing of the patented Adams process shows that destructive reactions take place between sulfur vapor and chemical agents mustard, GB, and VX as well as a broad range of organic compounds, including PCBs, chlorinated solvents, and the pesticide malathion.

Experimentation using this process at Pine Bluff Chemical Activity in Arkansas demonstrated that reactions take place between hot sulfur gases and dilute mustard agent as well as other agent simulants. The compounds were combined and mixed in a stainless steel reactor and heated to 857°F (458°C). The reaction products were examined using gas chromatography. The studies at Pine Bluff Chemical Activity indicated that the Adams process is effective in treating dilute mustard agent and simulant agents; however, more experiments are necessary to determine destruction efficiencies and kinetics (NRC, 1993).

Tests on the Adams process were also performed at Picatinny Arsenal in 1993 to investigate the treatment of energetic compounds through reactions with sulfur. The tests

used trinitrotoluene (TNT), cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (HMX), and pentaerythritol tetranitrate. The tests indicated that the reaction rate is a strong function of temperature and needs to be controlled below autoignition temperature. In cases where the energetic material contained its own oxidizer, autoignition drives a rapid oxidation reaction that could become explosive (NRC, 1993).

The Adams sulfur process has been used to treat chlorinated organic compounds in pilot-scale experimentation. Bench-top studies show promise as an effective treatment for energetic material and dilute mustard agent. Although the process could be used to treat metal parts, based on the work at Pine Bluff Chemical Activity, specific studies for this use have not yet been conducted. Adams process developers have indicated that the process is able to treat contaminated soils and materials contaminated with heavy metals. However, large amounts of water in the feed stream may hinder the process (NRC, 1993).

The process has been studied using several different size reactors, batches, and configurations that indicate the technology's has potential for incorporation into a transportable system and has flexibility in treating various batch sizes and feed streams. The chemistry of the Adams process is not fully developed, making it difficult to project scale-up problems and long-term stability of the solid products. Early testing indicates that most of the input compound by-products are incorporated into a carbon-sulfur polymer during treatment. Other waste products can be treated with conventional technology since the major constituents are found in more traditional industrial operations. Until large-scale tests can be conducted, however, it is not possible to accurately predict the chemical makeup or concentration of trace contaminants.

G.6.1.2 Catalytic Oxidation

Catalytic oxidation uses a furnace with a fixed-bed of catalyst with an oxidizing reactive environment (similar to an automobile catalytic converter).

Overview

The combustion, or burning, of organic vapors in the presence of oxygen (that is, oxidation) can be made to be more efficient using a catalytic material (Figure G-4). By using catalytic material inside a combustion reactor, the use of a lower temperature is possible while achieving the treatment goals in similar or shorter times. This can result in more efficient use of the fuel and can reduce levels of noxious compounds, such as nitrogen oxides in the gases exiting the combustion chamber.

Catalytic oxidation processes have been used commercially to treat various waste chemicals and have been shown, in laboratory tests, to be able to treat some chemical agents that have been diluted. The principle has been used in catalytic converters on automobiles for many years.

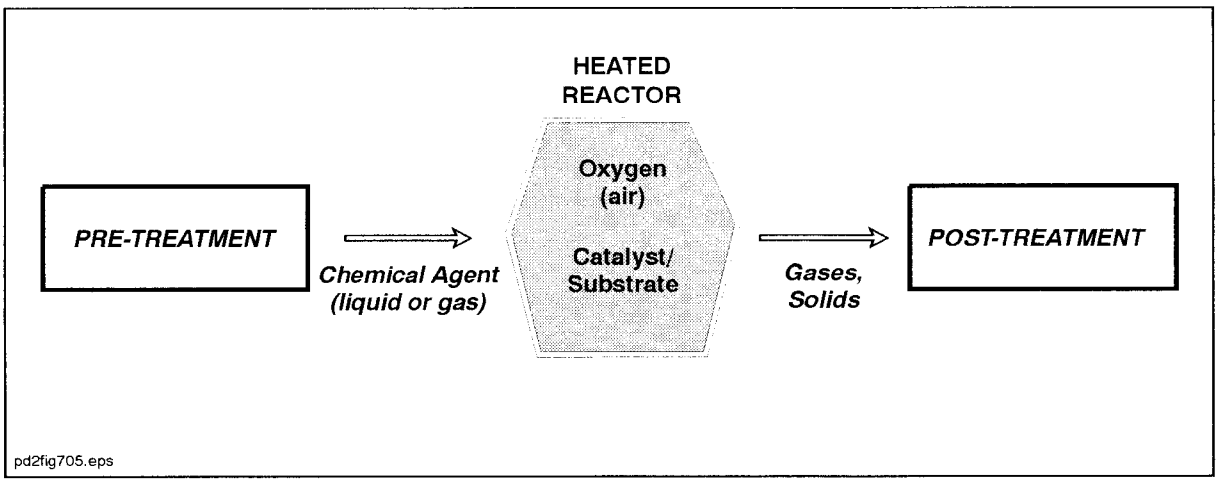

Figure G-4. Illustrative Diagram of Catalytic Oxidation

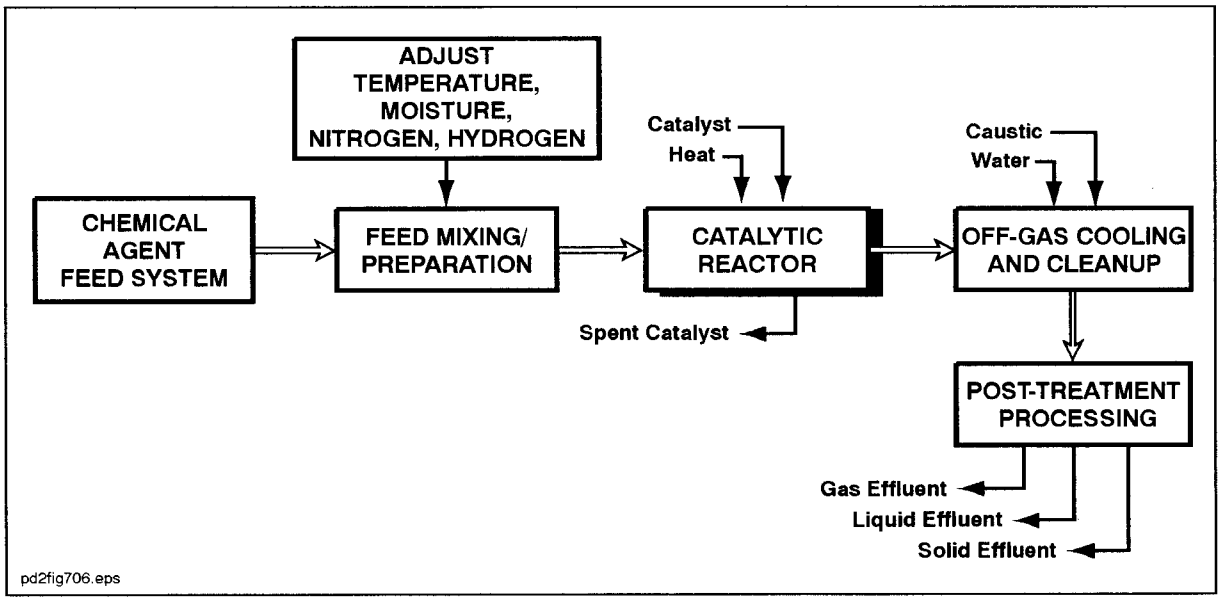

Figure G-5. Process Flow Schematic for Catalytic Oxidation

Description

Catalytic oxidation processes use a catalyst to enhance the thermal oxidation process by allowing lower operating temperatures and shortened residence times of the compounds to be treated in the combustion chamber. A catalyst is a substance that accelerates a reaction without itself being consumed.

Employing an oxidative catalyst to enhance the thermal oxidation process can treat various organic molecules using an oxidation catalyst in a temperature-controlled reactor at operating temperatures of about 500 to 1,110°F (260 to 543°C). This technology is normally applied only to very dilute gas streams. The process can treat volatile organic compounds containing halogens, sulfur, and phosphorus when they are included as a small percentage of the gaseous feed concentration (Department of the Army, 1994).

The catalytic reactor contains a catalytic matrix applied to an inert substrate. The catalytic material is applied to a substrate, which provides form and affects the flow path of the gases and which provides a supporting surface area upon which the catalytic material is adhered. The development of the technology has included studies of several different catalyst formulations and substrate configurations. The catalysts are generally coated on a surface that minimizes problems of drops in pressure, but increases the active reaction sites. The surface may also contain noble metals which are inactive (for example, silver, gold, and platinum) on a gamma-alumina washcoat to increase adhesion. Titanium dioxide and other proprietary metallic powders have also been applied to substrates designed to improve flow and reactive site properties (Chu, 1994). The industrial application of this technology is very similar to that used in the automobile industry to reduce emissions of unburned hydrocarbons and carbon monoxide in exhaust streams (NATO, 1996).

The basic process is illustrated in Figure G-5. The input air fed to the reactor chamber is pre-conditioned to correct the temperature and composition of oxygen, nitrogen, hydrogen, and moisture. The resulting gases are fed to the catalytic reactor, which may be externally heated. The process reaction off-gases include primarily water, carbon dioxide, sulfur dioxide, hydrogen fluoride, hydrogen chloride, and phosphorous pentoxide among other constituents, some of which require post-treatment processing to meet regulatory requirements. Some processes employing catalytic oxidation recirculate the off-gases to enhance treatment performance and conserve heat. Liquid products of oxidation and those resulting from the off-gas processing may need to be removed, possibly by using scrubbers or activated-carbon filters. Scrubber effluent brine contains unreacted alkaline materials and salts of chlorine, fluorine, sulfur, and phosphorus. Spent catalyst requires disposal in accordance with applicable requirements (NRC, 1993).

Development and Applicability

Thermal catalytic oxidation has been developed into an abatement method for chlorinated volatile organic compounds. This process primarily converts gaseous organic waste into

carbon dioxide and water. In this application, volatile organic compound treatment occurs at temperatures up to 1,112°F (600°C). Energy requirements are less than those for incineration are, and off-gas treatment is required to treat entrained products of incomplete combustion and acidic gases. Early applications of this process required frequent recycling or regeneration of the catalyst. Current catalysts are improved but still subject to process interactions (for example, sulfur and phosphorous poisoning, formation of metal agglomerations, masking, and fouling) that reduce the available active metal surface area and thus, reaction efficiencies (NRC, 1993).

Catalytic oxidation systems have been considered for use in conjunction with other chemical agent treatment systems in the following three ways: as an improved secondary combustion process, as a treatment step after secondary combustion, and as a treatment step following off-gas pollution abatement processing. Laboratory testing has been performed using low concentrations of mustard, GB, and VX in air (Allied Signal, 1997). A catalytic oxidation unit is being tested with HD, GB, and VX as part of the Assembled Chemical Weapons Assessment demonstration.

Catalytic oxidation is used commercially for the oxidation of trace hydrocarbons. Recent technological advancements have opened a new range of volatile organic control units to help meet new stricter emissions regulatory standards (Gay, 1997).

G.6.1.3 Direct, Fuel-Fired Combustion (Incineration)

Incineration refers to a furnace directly heated by the combustion of fuel with excess air to provide an oxidizing reactive environment.

Overview

During incineration processes, organic materials are burned in the presence of oxygen, which is usually provided by excess air. This combustion results in the organic materials fed into the incinerator being oxidized and broken into smaller molecules (Figure G-6). In order to facilitate the oxidizing treatment conditions, excess air (oxygen) is provided to the incinerator to ensure maximum oxidizing conditions are maintained. Incinerator operation uses the fuel value of the organic material being treated in addition to auxiliary fuels (for example, liquefied petroleum gas, natural gas, or jet fuel) as components of the fuel mix ratio Besides adequate mixing, the other two primary principles guiding efficient incinerator design and operation are the assurance of adequate temperature and residence time (that is, the time that the material being treated is held in the treatment reactor).

Incineration is used extensively in the hazardous waste industry, both in mobile and fixed-base systems, for the treatment of organic compounds such as polychlorinated biphenyls, pesticides, and herbicides, as well as for treatment of explosive-contaminated media. The United States has tested various incineration systems for treating chemical agent and has used the technology both to treat various agent types directly and as a secondary treatment process following chemical reagent neutralization. Although the United States is

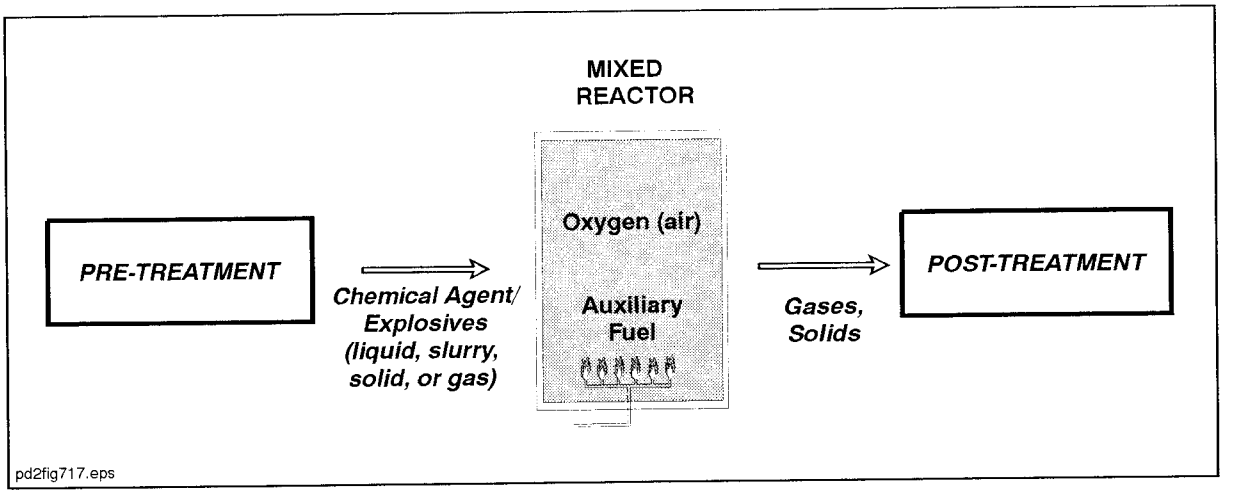

Figure G-6. Illustrative Diagram of Incineration Process

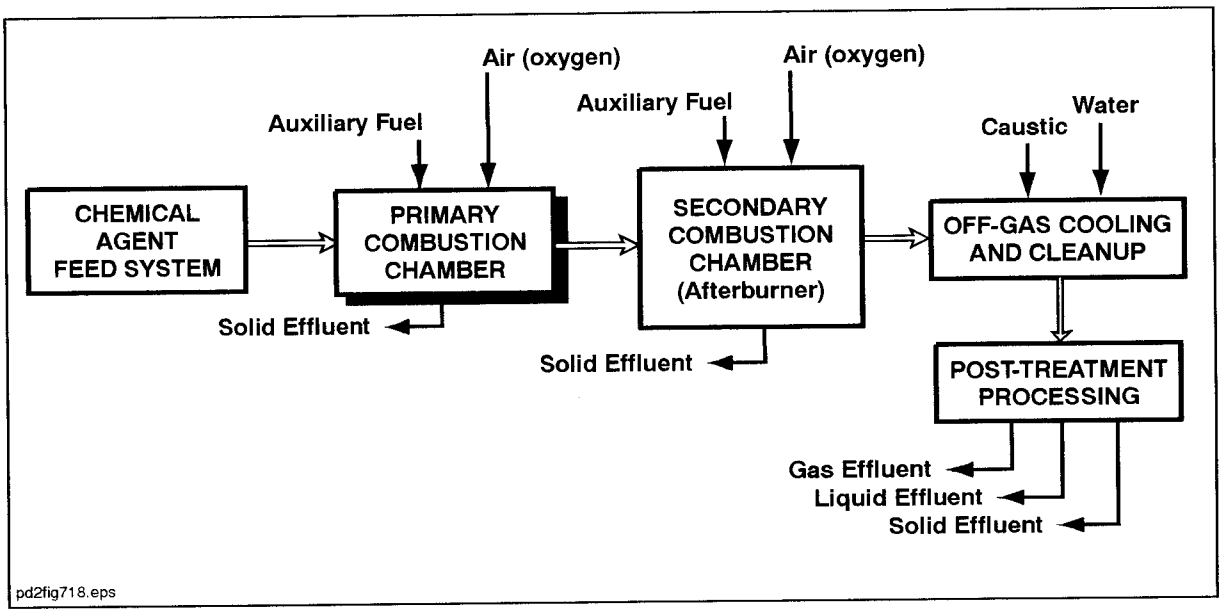

Figure G-7. Process Flow Schematic for Incineration Process

currently using incineration at fixed-treatment facilities for the destruction of part of the chemical weapon stockpile, a mobile system that has proven capable of meeting the demands of the non-stockpile demilitarization program has not yet been constructed and tested for that purpose.

Description

The basic incineration process for treatment of chemical agents is depicted in Figure G-7. After accessing the chemical agent in CWM, the agents are fed to a two-stage incinerator where heat is used in the presence of excess oxygen to drive the oxidation reaction. In the primary combustion chamber, the chemical agent is vaporized. The volatilized agent is immediately combusted at high temperature producing a flue gas containing carbon dioxide, water vapor, carbon monoxide, nitrogen oxides, and low concentrations of other compounds, depending on the chemical agent being incinerated.

The off-gas from the primary incinerator is passed to a second combustion furnace, or "afterburner", where heat is added to maintain a temperature of about 2,000 to 2,700°F (1,093 to 1,482°C) to treat products of incomplete combustion and any remaining agent. From the afterburner, off-gases require further processing in an pollution abatement system to meet clean air requirements before being exhausted to the atmosphere. The system is operated under negative pressure to minimize the escape of untreated gases from the system.

The U.S. Army designed and constructed a prototype incineration system in the early 1970s to support development of the U.S. Chemical Stockpile Disposal Program at the Chemical Agent Munitions Disposal System at the Deseret Chemical Depot, Utah. Testing of this system provided the design, operational, and maintenance improvements for the Army agent incineration disposal system design, and is still providing data for the chemical agent (and munition component—including energetic materials) incineration design improvements. The U.S. Army is currently operating two incineration systems for the treatment of stockpile CWM at Johnston Atoll and Deseret Chemical Depot in Utah. These systems use a variety of furnaces including static, tunnel, fixed-hearth, and a rotary retort all followed by static furnace "afterburners". Liquid chemicals are sprayed into a static furnace. Explosive components are sheared and fed to an explosion-rated rotary retort, which is followed by an electrically heated tunnel furnace. Metal bodies are fed on trays through a tunnel furnace. Solid secondary wastes (e.g., packing material, cloth, personnel protective equipment, etc.) are also fed to a furnace. The treatment maintains exposure time at temperature to ensure complete combustion. For liquid, the temperature is about 2,200 to 2,700°F (1,100 to 1,500°C) for approximately 2 seconds, while the other typically operate at lower temperatures and increased residence times.

Development and Applicability

The treatment of agent by incineration has been characterized as a mature technology because of prior use in treating U.S. stockpile CWM. There are many different operating

designs for incineration systems that offer tradeoffs regarding operational parameters, input feed requirements, monitoring and control adaptability, and transportability. Various liquid and gelled chemical agents have been treated in testing at the Chemical Agent Munitions Disposal System using different incineration systems and operational approaches. For example, agent has been batch treated in open containers, in rotary kilns, and roller-hearth furnaces. Agent has been injected into these furnaces to test various scenarios involving temperature, loading quantities, residence-times, and feed systems. For maximum potential utility at non-stockpile CWM sites, the *Generic Site Scoping Study* (Department of the Army, 1993) suggested the use of an inclined rotary kiln. Transportable incineration units for a variety of organic materials from Superfund cleanup sites have been demonstrated by the EPA using a rotary kiln incinerator mounted on skids or directly on trailers that meet U.S. Department of Transportation and state regulations for highway transport (EPA, 1990). The Canadian Defence Research Establishment Suffield has also used a specially adapted rotary kiln fitted with an afterburner to treat mustard, contaminated metal hardware, miscellaneous contaminated waste, and the neutralization by-products of G-series and VX nerve agents (McAndless, 1995). Rotary kilns can be used to treat energetic materiel that are separated from CWM, and to decontaminate metal parts. Specially designed stationary rotary kilns have also been used in tests using various chemical agents, energetic materials, and munition metal parts that have been fed to the kiln in a solidified (cryo-cooled) state after having been exposed to liquid nitrogen to reduce temperatures to below — 200°F (128°C) (Department of the Army, 1987).

Incineration system afterburners have been used to treat spent decontamination solutions. While effective, this results in the formation of a sticky, low-melting point particulate and forms a molten slag that must be removed and disposed. The use of a heat-resistant insulating firebrick, or refractory, is necessary to protect the steel sides of the afterburners and some primary burners that operate at high temperature. The insulating firebrick, or refractory, is material that is relatively fragile, requires maintenance, and is usually not used when treating explosive materials that may cause damaging blasts.

Transportable incineration systems have been used for many years to treat hazardous wastes and many different media, including soils contaminated with explosives. Although recent regulatory permitting and public opposition has reduced the numbers of commercially available transportable units, adaptation to meet requirements for agent destruction is considered a viable engineering alternative.

G.6.1.4 Fixed-Bed Furnace Oxidation

Fixed-bed furnace oxidation is a fixed-bed furnace with an oxidizing reactive environment.

Overview

Thermal media oxidation processes use a reactor containing a stationary bed that is heated to temperatures high enough to oxidize the organic waste materials fed to it. Gases are

forced through the holes in the bed, which not only heats the material but also acts to mix oxygen (usually provided as input air) and the gaseous waste material to promote efficient reactions (Figure G-8). The process is very similar to fluidized-bed oxidation except that the bed is stationary instead of being suspended by an upward gas flow. Fixed-bed furnaces have been used to treat many different kinds of organic liquid wastes and soils contaminated with polychlorinated biphenyls. Treatment of chemical agents or explosive materials has not been documented using thermal media oxidation.

Description

The thermal media oxidation process is used to treat organic materials using an inert, non-catalytic packed bed consisting of a ceramic metal oxide matrix contained in a reactor lined with insulating refractory. External heat applied to the reactor bed is required to maintain temperatures at 1,600 to 2,000°F (871 to 1,093°C). Fuel gas (for example, methane) can also be added to the input material being treated, depending on the heating characteristics of the material (DoD, 1995).

Figure G-9 illustrates the basic process steps utilizing a thermal media oxidation process to treat the breakdown and residual compounds in an off-gas stream, resulting from initial treatment. The reactor bed is first heated by an external preheater and sustained at the operating temperature by the heat of oxidation of the organic vapors. Organic vapors are combined with oxygen in the mixing zone of the bed and rise into the reaction zone, where the gas temperature increases rapidly due to the heat of combustion as the organics are oxidized. Passage of the gas through the small interstitial spaces within a ceramic bed matrix encourages a high degree of turbulence. The organic vapors and oxygen move upward through the bed as a uniform front with several zones. In the mixing zone, a high degree of turbulence results in efficient mixing of oxygen with the organics. The turbulent mixing also encourages effective heat transfer between the gases and the high temperature reaction zone. Oxidation is usually completed with the first few inches of the reaction zone, allowing for a relatively compact system. The process relies primarily on oxidation reactions that utilize the reactive hydroxyl free-radical ($OH^{\cdot}$), and is operated with excess oxygen in the feed stream.

Treatment of chemical agent using this process has not been tested, however, the off-gas is expected to contain nitrogen, oxygen, carbon dioxide, sulfur dioxide, hydrogen chloride, hydrogen fluoride, and phosphorous pentoxide.

Development and Applicability

Between 1987 and 1991, three experimental units were tested by commercial industry. These units were used to verify emission control and operational characteristics of the process treating various organic compounds. Twelve units have been installed or are under construction. Development has included design of a system to process off-gas from a thermal desorber that would be capable of treating soils contaminated with volatile organics. Thermal oxidation has been used commercially for several years with a broad range of system sizes

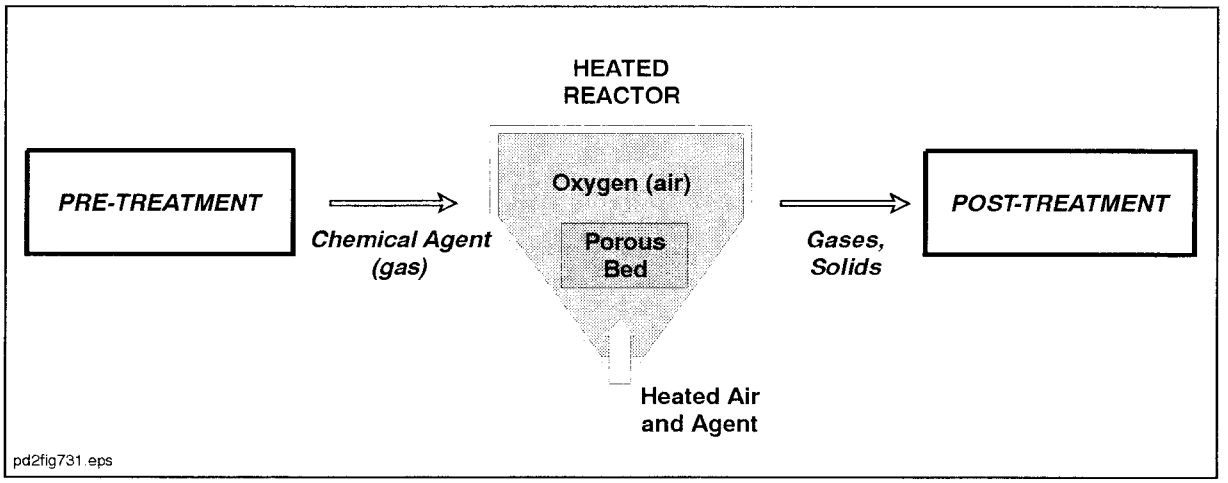

Figure G-8. Illustrative Diagram of Fixed-Bed Furnace Oxidation

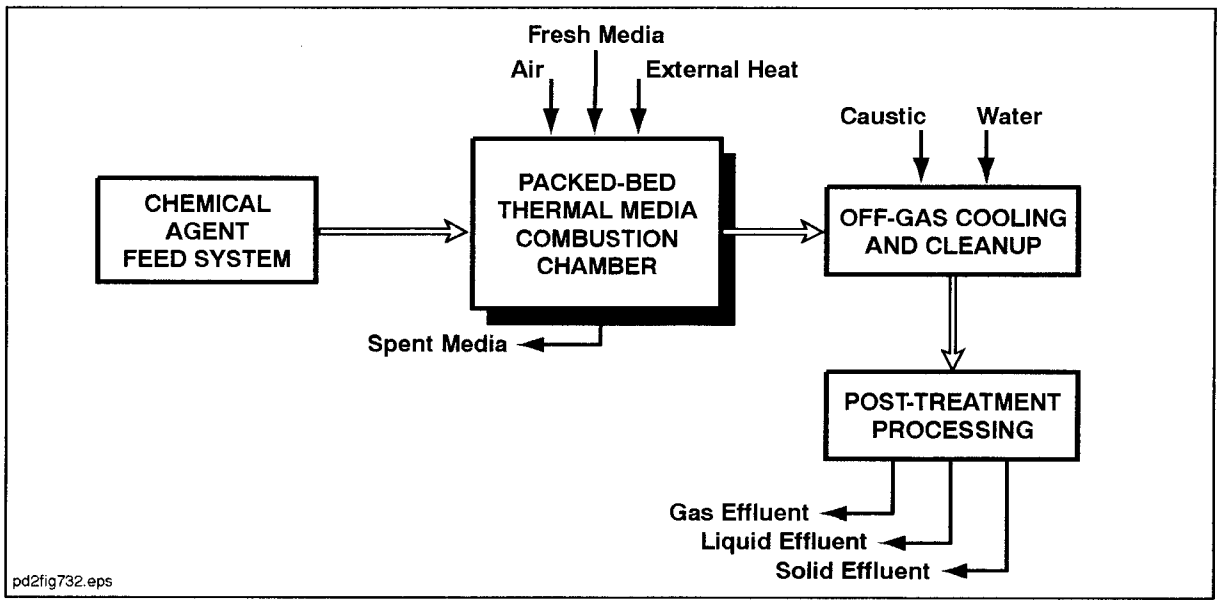

Figure G-9. Process Flow Schematic for Fixed-Bed Furnace Oxidation

and treatment capacities. Industrial applications include treatment of petroleum, petrochemicals, pharmaceuticals, agricultural chemicals, and soils contaminated with polychlorinated biphenyls. The process has been proposed for use as a chemical agent treatment technology, as a post-treatment process to treat the off-gas stream from a chemical agent treatment process, as a step after post-treatment but preceding a pollution abatement system, or as an off-gas treatment step after emission abatement (DoD, 1995).

G.6.1.5 Fluidized-Bed Oxidation

Fluidized-bed oxidation is a fluidized-bed furnace using air to provide an oxidizing reactive environment.

Overview

Under fluidized-bed oxidation, granular particles such as sand or limestone are suspended in a reaction vessel by air forced up through the vessel, forming a fluidized bed. By adjusting the flow of air, which supplies the oxygen for combusting (burning) auxiliary fuel and organic material to be treated, the particles are maintained in an agitated state similar to boiling liquid (hence the term fluidized bed) (Figure G-10). The material to be treated is injected beneath the surface of the bed where it mixes with the air and is brought into contact with the bed material.

The technology, which has been used for many years as a means to burn coal, has been adapted recently for possible use as a treatment technology for oxidizing organic wastes injected into the bed (NATO, 1996). Slurries containing hazardous wastes or explosive materials have been treated in pilot-scale equipment by the Army and the U.S. Environmental Protection Agency (USEPA).

Description

The fluidized-bed reactor consists of a vessel filled with a granular material, usually sand or limestone. Calcium oxide and oxides of iron, chromium, magnesium, copper, and other metals have also been placed on spherical alumina beads to help catalyze the reaction, and for added bed performance. As depicted in Figure G-11, air and auxiliary fuel, as needed, is mixed with the agent feed stream in the bed of the reactor. Air, which provides the oxygen for the combustion process, is forced upward through the bed, causing it to assume a state of agitation similar to that of a boiling liquid, hence the term "fluidized" bed. Wide ranges of air velocities have been tested, which resulted in a variation of bed densities and resulting performance characteristics. The material to be treated is injected beneath the surface of the bed where it is quickly mixed with the bed material. To improve treatment performance, catalytic material (for example, nickel) may be added to the slurry being fed to the reactor. Adjustments of the fuel, waste, air rates, and the selection of bed material are used to control the process (NATO, 1996).

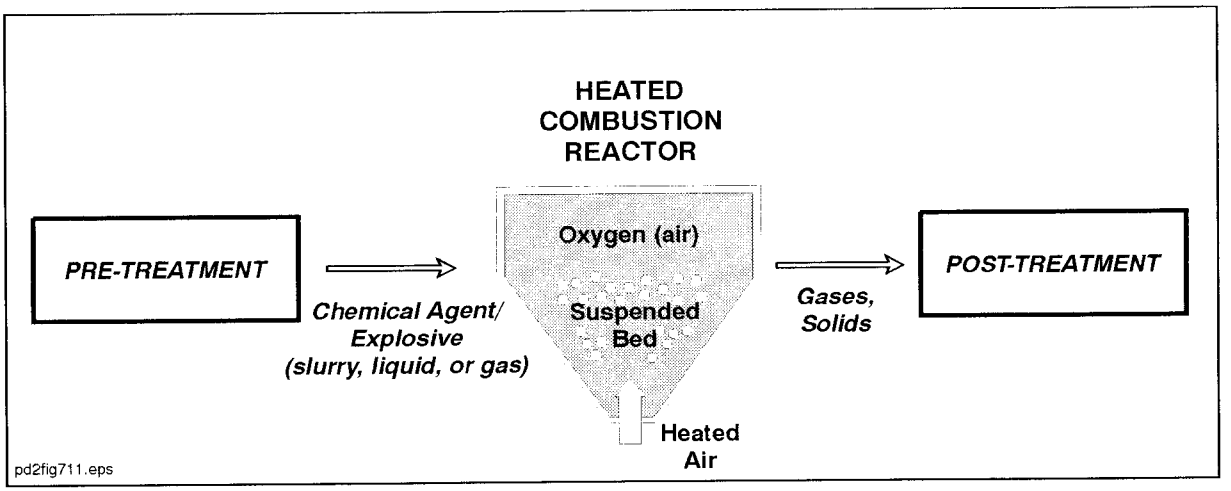

Figure G-10. Illustrative Diagram of Fluidized-Bed Oxidation

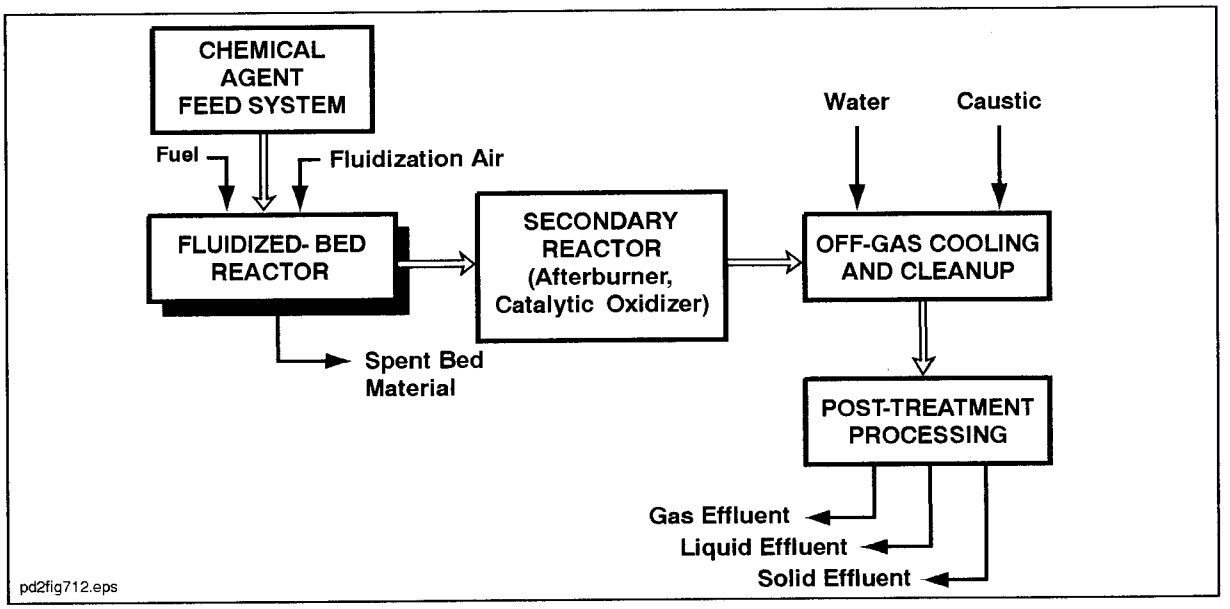

Figure G-11. Process Flow Schematic for Fluidized-Bed Oxidation

Fluidized-bed oxidation is a process that oxidizes organic compounds. The bed itself acts as a well-mixed reactor where the contact of the suspended material with the material to be treated is optimized. The mixing promotes efficient heat and mass transfer for treatment of the feed material. The materials absorb heat generated from the combustion of the waste and from auxiliary heat, which provides a moderating thermal mass for the thermal oxidation of the organics being treated. The process is usually operated at a temperature range of about 1,110 to 1,850°F (599 to 1,010°C). The bed particles can also undergo reactions when the granular material itself is made up of a catalytic material or the particles are coated with a selective catalyst (Department of the Army, 1994).

Ash and noncombustible materials are discharged from the bottom of the vessel for ultimate disposal. The bed material must periodically be removed and disposed of, and fresh makeup material (that is, new bed material to replenish that which becomes ineffective or damaged during continued use) added. The exhaust from the reaction chamber is passed through a hot cyclone and the solids are circulated back to the reactor chamber. The gas stream is further treated as necessary (for example, by an afterburner or catalytic oxidizer), and then passed to a pollution abatement system for final cooling and off-gas cleanup.

The primary components in the off-gas are nitrogen, oxygen, water, and carbon dioxide. During the treatment of chemical agent, it is expected that sulfur dioxide, hydrogen chloride, hydrogen fluoride, phosphorous pentoxide, and low levels of various organic compounds would also be present in the off-gas, depending on the agent being treated. If the bed material contained lime or dolomite, it is likely the concentrations of some of the acidic gases (for example, hydrogen chloride, hydrogen fluoride, and sulfur dioxide) could be reduced. The off-gas stream may also contain concentrations of incompletely treated organic compounds, which may also require further treatment in the final pollution abatement processing (NRC, 1993).

Development and Applicability

Fluidized-bed systems have found greatest use in the combustion of coal for purposes of steam and power generation. Coal or other combustible fuels are injected into a limestone bed where the heat generated is absorbed by steam tubes, and sulfur dioxide is absorbed by the limestone. More recently, the fluidized-bed technology has been adapted to the treatment of hazardous waste. Slurries of organic materials with concentrations of up to 25 percent in water have been successfully used in a commercial-size unit. Fluidized-bed incinerators have also been successfully used to treat explosives and propellants as well as organic compounds in mixed waste with low-level radioactivity from nuclear power plants, pesticides, polychlorinated biphenyls, and a wide variety of other hazardous and nonhazardous materials, chemicals, and waste products (NRC, 1993).

A slurry of 25 percent TNT was fed to a catalytic fluidized-bed reactor operated at Picatinny Arsenal for about 1 year at about 360 pounds per hour (45 grams per second) (NRC, 1993). The unit was8 feet (2.4 meters) in diameter and 30 feet (9.1 meters) high with a charge of about

22,000 pounds (9,980 kilograms) of alumina. The EPA has also demonstrated a related technology for hazardous waste treatment. Catalytic fluidized-beds have been developed for use in transportable units. In separate tests using prototype equipment, a wide range of organic solvents and wastewaters containing chlorinated organics were treated (NATO, 1996).

G.6.1.6 Gas-Phase Chemical Reduction

Gas-phase chemical reduction uses electrically heated furnaces in a hydrogen environment with steam as a means of heat transfer.

Overview

The gas-phase chemical reduction process chemically reduces organic wastes in an atmosphere of steam and excess hydrogen. Organic material in the form of either a liquid or vapor is fed to the reactor vessel that is heated and maintained at a slight positive pressure to prevent air (oxygen) from entering, which would reduce the efficiency of the reduction reactions (Figure G-12). The waste to be treated is introduced into the reactor either as a liquid or gas. Methane gas is formed from the breakdown of organic compounds, which further reacts with organic compounds and water in the reductive environment to form hydrogen gas, carbon monoxide, and carbon dioxide. This process is similar to the hydrogenation process discussed in subsection G.6.1.7, except that no catalyst is used and pressure is not needed to drive the reaction as required in hydrogenation processes.

This technology has been used to treat wastes such as oils and wastewaters containing polychlorinated biphenyls and other organic compounds. Laboratory testing has also shown that preparations of mustard agent and nerve agent (VX) can be treated using this process.

Description

The basic gas-phase chemical reduction process is illustrated in Figure G-13. The reactor, containing hydrogen and hot recycled gases is also heated by an auxiliary source to increase temperatures to about 1,600°F (871°C). Additional heat could be provided to the reactor vessel internally or externally (for example, electric-heating elements). The pressure in the reactor vessel is maintained slightly above atmospheric pressure to prevent air infiltration. Since the process requires that the physical state of the feed be either gaseous or liquid, solid materials contaminated with residual agent would need to be processed (for example, size-reduced and slurried) and the agent evaporated in separate subsystems. The resulting volatilized agent is fed to the main treatment reactor.

The process breaks down organic molecules into a gas containing methane, carbon monoxide, carbon dioxide, and trace amounts of light hydrocarbons. Following treatment, the gas could be processed through a number of treatment or recovery subsystems, which would depend on the type of waste being treated. There is some uncertainty in the exact constituency and management of the inorganic by-products derived from chemical agent treatment (for example, sulfur, phosphorous, nitrogen, and fluorine) because of limited

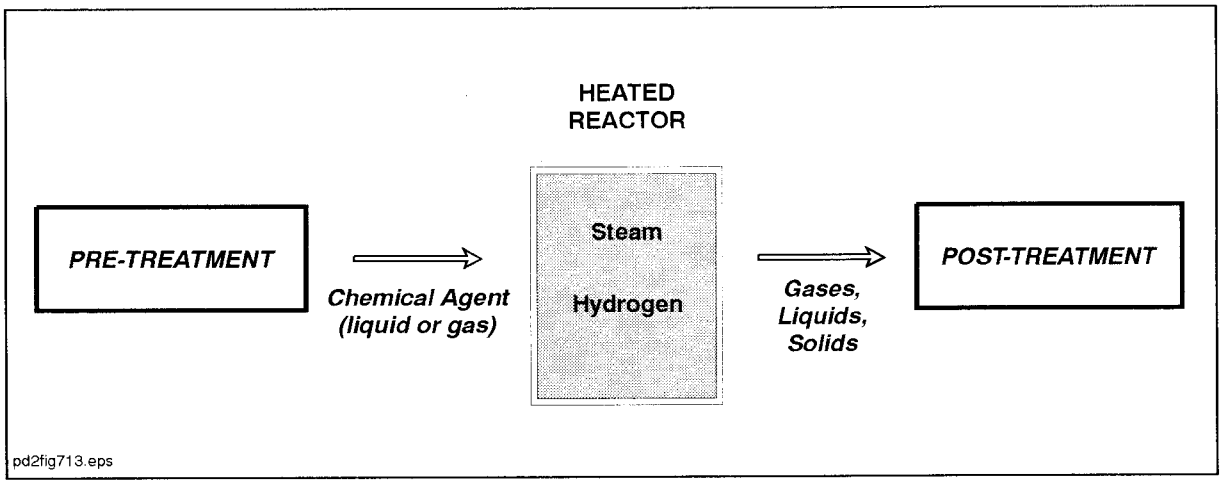

Figure G-12. Illustrative Diagram of Gas-Phase Chemical Reduction

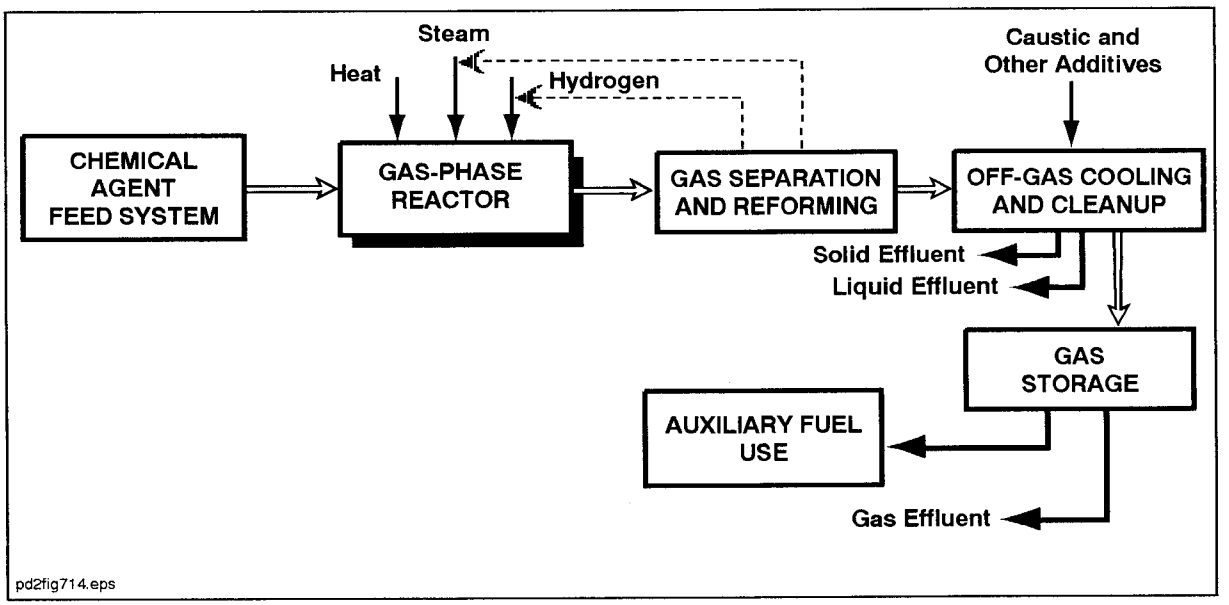

Figure G-13. Process Flow Schematic for Gas-Phase Chemical Reduction

testing. The process reduces organic carbon to methane, chlorine to hydrogen chloride or hydrochloric acid, and sulfur to hydrogen sulfide.

The hydrogen chloride produced could be recovered as acid or scrubbed out in a caustic scrubber downstream of the process reactor. A portion of the gas could be recycled back to the reactor, and the remainder could be compressed for storage and tested prior to reuse in process-related subsystems (for example, the boiler). The main process reaction essentially breaks down organic compounds and re-forms them into methane, the main component of natural gas. The use of recovery and recycling steps would depend upon specific design features of the developer (NRC, 1996).

All reactions in the process are reductive in nature, with the exception of the reaction between water and methane to generate hydrogen, carbon monoxide, and carbon dioxide. These "steam reforming" or "water-shift" reactions, which are accomplished in the steam reformer and to some extent in the reactor itself, generate additional hydrogen to further facilitate the reduction of organic compounds. Besides reacting with methane to re-form hydrogen, the addition of water or steam enhances the overall treatment process because water also acts as a reduction agent and as a means of transferring heat.

Some "proof-of-principal" testing has been conducted on VX and HD with a gas-phase chemical reduction unit. The major reductive breakdown products of mustard agent and VX are methane and water. If a molecule of agent contains chlorine, as in the case of mustard agent, hydrogen chloride is produced. The sulfur present in both mustard agent and VX are reduced to hydrogen sulfide. The nitrogen in VX forms nitrogen or ammonia. The phosphorous in VX may undergo numerous reduction scenarios that involve various intermediate phosphorous-containing compounds. Phosphine is considered the most probable form to exit the process reactor, but testing to date has not indicated this product (NRC, 1996).

Development and Applicability

Development of the gas-phase chemical reduction process has been conducted for over 10 years by ELI Eco Logic International, Incorporated, of Rockwood, Ontario, Canada. Eco Logic has obtained permits for projects at two commercial-scale facilities, one in Canada and one in Australia, and one pilot-scale facility in the United States. During a test conducted in 1992, at the pilot plant facility, the system processed 2–6 metric tons (2.9 tons) of wastewater and about 0.2 metric tons of oil contaminated with polychlorinated biphenyls. This test demonstrated that the process could treat polychlorinated biphenyls and that the resulting stack emissions could meet U.S. air quality regulations (Department of the Army, 1996b).

The process has demonstrated effective treatment of various organic waste steams such as toluene, polynuclear aromatic hydrocarbons, polychlorinated biphenyl residuals in oil, and soil in pilot-scale tests. The process is being used in a project in Canada to treat polychlorinated biphenyls and in Australia for treatment of residual polychlorinated biphenyls and dichlorodiphenyltrichloroethane, or DDT. Necessary equipment and support components of the

process have been mounted on standard highway trailers for transport to sites utilizing this treatment method (Department of the Army, 1996b).

In support of the Alternative Technology Program, which is investigating alternative treatment methods for the treatment of chemical weapon stockpiles of mustard agent at the Edgewood Chemical Activity, and nerve agent VX at the Newport Chemical Depot, testing was conducted in the toxic test chambers operated by the Edgewood Research and Development Engineering Center. The facilities were made available to Eco Logic for testing of small quantities of mustard agent and the nerve agent VX in equipment designed to mimic the full-scale process.

G.6.1.7 Hydrogenation Processes

Hydrogenation processes use a furnace with catalyst and pressurized hydrogen to produce a reducing reactive environment.

Overview

Hydrogenation processes use pressure, heat, and a catalyst to break down organic compounds in a reactor filled with gas containing mostly hydrogen (Figure G-14). As discussed previously, a catalyst is an additive that makes the chemical reactions occur more efficiently without actually being used up in the reactive by-products. The waste materials to be treated are reduced in a series of reactions involving methane, which is generated in the reactor, to hydrogen gas, carbon monoxide, carbon dioxide, and several other small compounds. The process chemistry can be controlled by varying the type and amount of catalyst.

Hydrogenation, sometimes called hydrocracking or hydrotreating has been widely practiced in the petroleum refining industry to break down heavy petroleum into smaller by-products. It is primarily used to remove compounds containing oxygen, nitrogen, or sulfur from various petroleum fractions by converting them into water, ammonia, hydrogen sulfide, and various hydrocarbons.

Description

Hydrogenation processes operate in a temperature range from about 750 to 930°F (399 to 499°C) and pressures ranging from 150 to 1,500 pounds per square inch (10 to 105 kilograms per square centimeter). Excess hydrogen is needed, typically about 80 percent by volume. A catalyst is also needed that is suitable for use with all chemical agents or specific catalysts are needed for each agent, depending on the reaction desired (NRC, 1993).

Figure G-15 illustrates the basic hydrogenation process. The process involves combining a liquid feed in a common vessel with a reaction-specific catalyst and any other additives (for example, lime) to control the reaction and associated by-products and waste streams. The mixture is then fed to the main reactor, which contains a large excess of hydrogen under pressure. External heat augmentation may be required in either or both reaction process

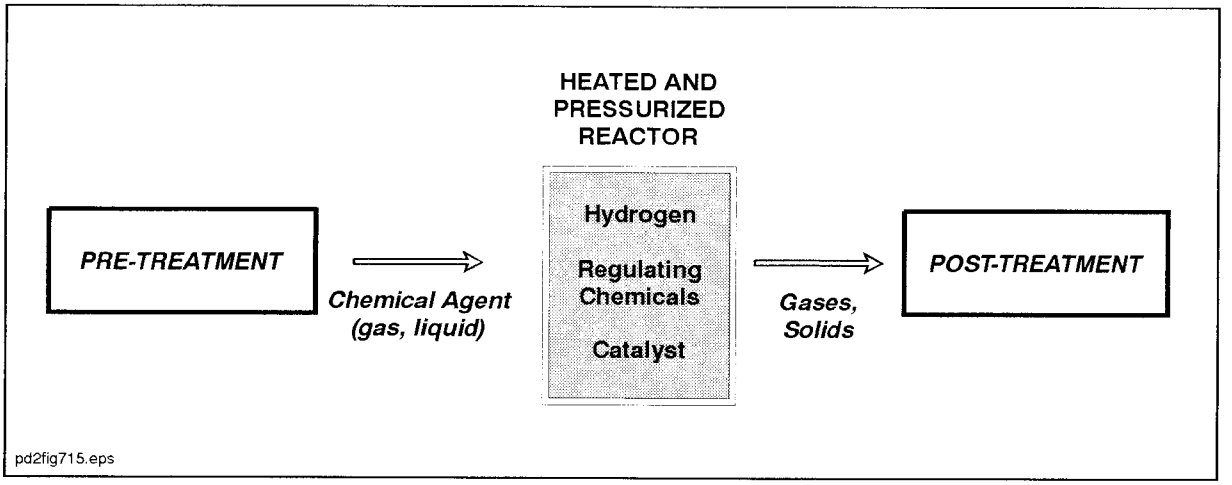

Figure G-14. Illustrative Diagram of Hydrogenation Process

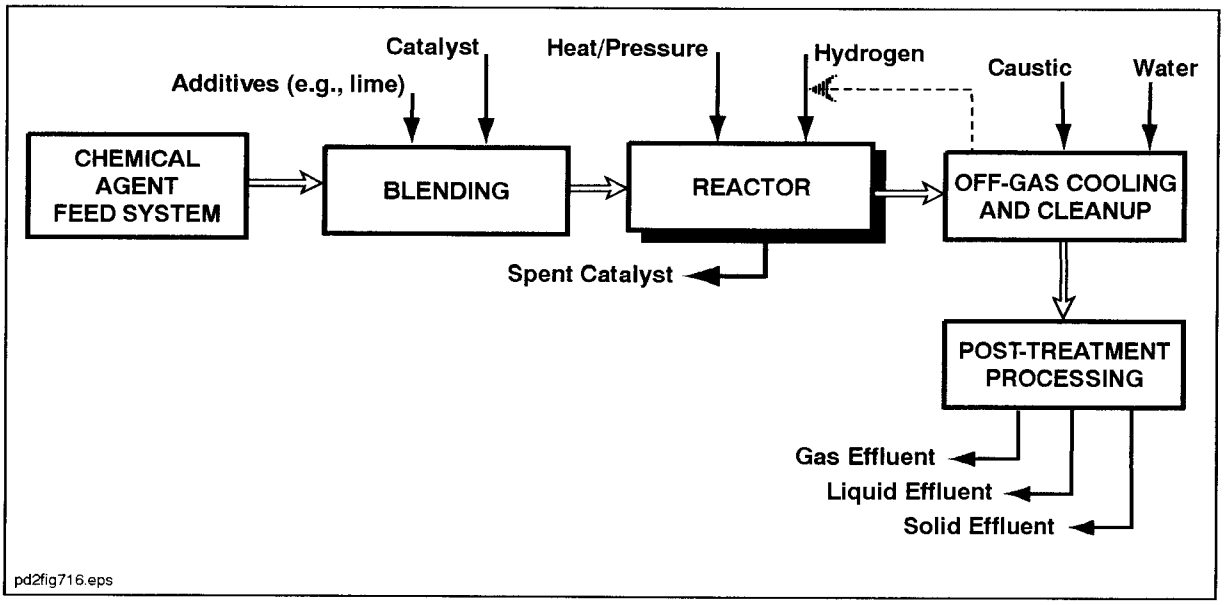

Figure G-15. Process Flow Schematic for Hydrogenation Process

stages. Hydrogenation generates heat, but the large excess of hydrogen limits the temperature rise, allowing the hydrogenation processes to operate in a stable manner.

Off-gas from treating chemical agents is expected to contain acidic gases and a combustible synthesis gas. Gaseous waste streams of hydrogen chloride, hydrogen fluoride, hydrogen sulfide, and possibly phosphine are produced in a dilute mixture with hydrogen. If these materials have an adverse effect on the catalyst performance, they are separated from the hydrogen by distillation. After reducing the off-gas temperature, acid gases are neutralized and scrubbed to form wastewater brine. Alternatively, there is also the potential for acid recovery from the off-gas. The synthesis gas can be captured and probably compressed and analytical procedures could be used to verify that treatment standards for the off-gas have been met. A solid waste stream composed of residue and spent catalyst is taken from the catalytic hydrotreating reactor (NRC, 1993).

Development and Applicability

The use of hydrogenation for treatment of hazardous compounds similar to chemical agents is limited. There has been no reported use of the process for agent treatment. However, the process offers several features that may be attractive compared to other technologies. The product streams are expected to be small in volume compared with those of oxidation processes and they can be retained for sampling and analytical testing to verify treatment effectiveness before release. If the treatment is found incomplete, the effluent streams are recycled for further treatment. Recovered gases (for example, methane, ethane, propane, and hydrogen) from the process off-gas can be used as fuel in the plant to generate heat (NRC, 1984).

G.6.1.8 Molten Metal Catalytic Extraction

Molten metal catalytic extraction is a molten media (metal) furnace that typically uses a reduced-oxygen and light hydrocarbon gas (e.g., natural gas, propane, methane, etc.) for a reducing and slightly oxidizing reactive environment (to form a synthesis gas).

Overview

The molten metal catalytic extraction process uses a high temperature bath of liquefied, or molten, metal contained in an insulated reactor vessel to breakdown organic compounds, melt metallic compounds, and melt other inorganic materials (for example, salts) (Figure G-16). The materials to be treated are placed into the molten metal bath, which may be pressurized depending on the process. The metal in the bath acts as a catalyst to assist in the reactions that breakdown the organic wastes being treated in an atmosphere with a limited amount of oxygen. Chemical additives can be added to the metal bath to adjust the chemical reactions that occur.

The molten metal process is similar to what has been used in steel production but has been further developed as a treatment process for waste compounds. Oxidation reactions occur in the molten metal bath. Oxygen and methane can also be added to the reactor for various purposes including mixing, cooling, and to assist the treatment reactions. Trial tests have been performed using this technology to treat mustard, nerve agents, and agent simulants.

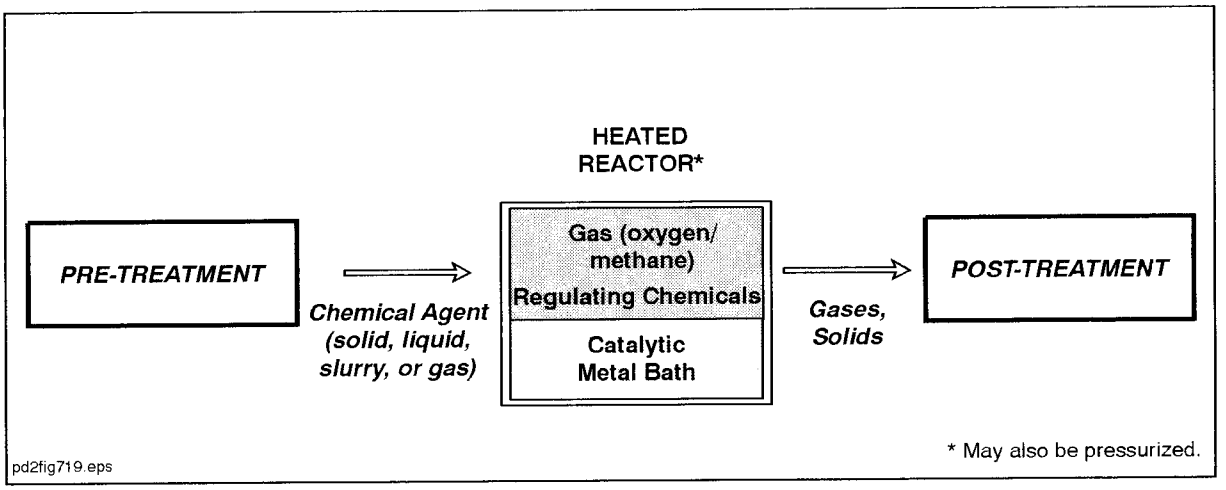

Figure G-16. Illustrative Diagram of Molten Metal Catalytic Extraction

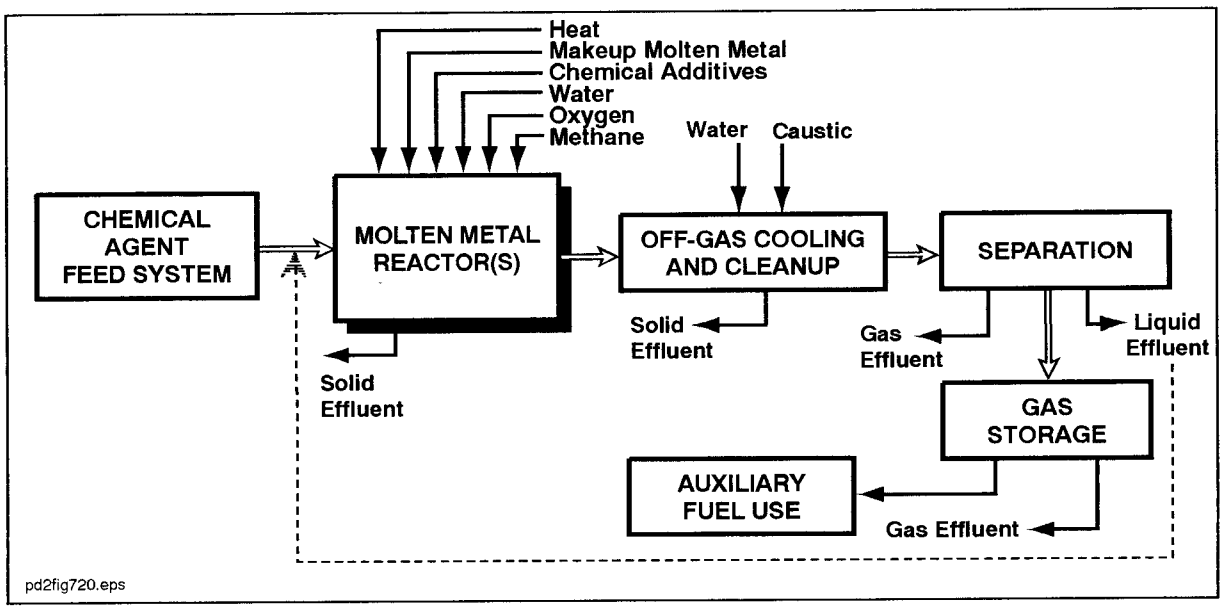

Figure G-17. Process Flow Schematic for Molten Metal Catalytic Extraction

Description

In the molten metal process, the materials to be treated are placed into a molten metal bath composed of metals such as copper, iron, nickel, or cobalt. The bath can catalytically decompose organic compounds, which are further processed in the reactor vapor space above the bath, and can melt inorganic materials forming a slag that is removed from the surface of the bath. The molten metal technology used in steel manufacturing is being developed to treat recalcitrant chemicals at temperatures ranging from 2,500 to 3,000°F (1,371 to 1,649°C) (NRC, 1996).

The catalytic extraction process utilizing molten metal is depicted in Figure G-17. A molten metal reactor is a steel pressure vessel lined with refractory materials to provide thermal insulation and resistance to chemical and physical degradation by components of the bath. An electric induction coil provides energy to melt the metal charge and maintain the temperature of the bath during processing. The space in the reactor above the metal bath must be of sufficient size to allow vapors to escape the metal bath and for chemical reactions to be completed before being passed to the off-gas treatment systems. The slag, which is a by-product of the process reactions that floats on the surface of the metal bath, is removed as it accumulates during the treatment process. New metal is added to the bath as required during continuous treatment (NRC, 1996).

The material to be treated, which may be liquid, gas, or finely divided solids suspended in a pumpable slurry, is metered, mixed, and pumped into the reactor. Oxygen and methane is also metered into the vessel to provide for the necessary components of chemical reactions in the metal bath, to induce turbulence to enhance mixing, and to cool the injection ports. A significant fraction of the material being treated undergoes partial oxidation, and the products of partial oxidation then interact with the molten metal to form intermediate by-products (Department of the Army, 1996b). These intermediate by-products decomposed in the catalytic metal bath into their component elements (for example, carbon, sulfur, and phosphorous). Some intermediate by products also react with less soluble elements (for example, hydrogen, oxygen, and chlorine) to form gaseous products (for example, hydrogen, carbon monoxide, hydrogen chloride, hydrogen sulfide, and smaller amounts of carbon dioxide, nitrogen, and water). The elements present in chemical agents are converted: carbon to carbon monoxide, hydrogen to hydrogen gas, sulfur to hydrogen sulfide, and chlorine to hydrogen chloride or hydrochloric acid (NRC, 1996).

Development and Applicability

Catalytic Extraction Processing (CEP) has been developed for treatment of hazardous wastes and was patented by the now defunct Molten Metal Technology of Waltham, Massachusetts. At one time, there were three commercial scale facilities, one in Massachusetts and two in Tennessee, in varying stages of operational checkout and preoperational testing. The status of the CEP systems since Molten Metal Technology went bankrupt is unknown. CEP has been designated by the EPA as a non-incineration technology.

The CEP process was presented by the developer for consideration by the Army for treatment of the stockpile of mustard agent at the Edgewood Chemical Activity and for the stockpile of VX at the Newport Chemical Depot. As presented, the first reactor contains molten nickel maintained at a pressure of about 14.7 pounds per square inch (1 kilogram per square centimeter). The second reactor is charged with iron and pressurized at about 30 pounds per square inch (2 kilograms per square centimeter). The primary and secondary reactors both operate at 2,700°F (1,482°C). Solids are processed in the primary unit, with the secondary unit receiving the gas stream from the primary unit to further treat the off-gas. Liquid VX agent is injected into the primary unit through inlet piping underneath the pool of molten metal. Mustard agent is injected into the higher-pressure secondary unit and through piping in the bottom of the molten metal pool. One or more tapping ports through the vessel sidewall allows removal of metal and slag (NRC, 1996).

In the gas handling subsystem, the off-gas is cooled and processed through a high temperature ceramic filter. The filtered solids are recycled to the reactors and the gas requires further cooling. Elemental sulfur, also a solid, is removed from hydrogen sulfide in the gas train. The only liquid effluent expected is a stream scrubbed from the off-gas in the gas treatment subsystem containing hydrochloric acid. The gas treatment system also generates a gas composed of mostly carbon monoxide and a small percentage of hydrogen. The hydrogen is stored for later use in the process (for example, burned to fire electrical generator turbines), or vented after analytical testing to verify that it meets emissions requirements (NRC, 1996).

Molten Metal Technology has conducted chemical agent surrogate testing and has conducted trials using mustard and the nerve agent VX. Subsequent chemical agent treatment tests were conducted at the Battelle Columbus Laboratory in a bench-scale CEP unit (Department of the Army, 1996b).

G.6.1.9 Molten Salt Oxidation

This is a molten media (salt) furnace with an oxidizing reactive environment.

Overview

Molten salt oxidation is a process in which organic chemicals are decomposed in a pool of hot liquefied, or molten, salt. The material to be treated would be mixed with any chemical additives to assist the reaction, and then pumped to the brick-lined reactor vessel containing the molten salt that would be temperature-controlled. The salts used to form the molten pool can be varied to meet particular process needs and act as a catalyst to enhance oxidation reactions that occur in the hot melt. Air, which is introduced to provide oxygen and mixing, traps the reaction by-products that rise through the hot molten salt as bubbles (Figure G-18). The treatment of many of the waste materials results in the formation of materials that remain within the molten pool instead of leaving the reactor in the gas stream (off-gas). This can reduce the off-gas post-treatment processing needs.

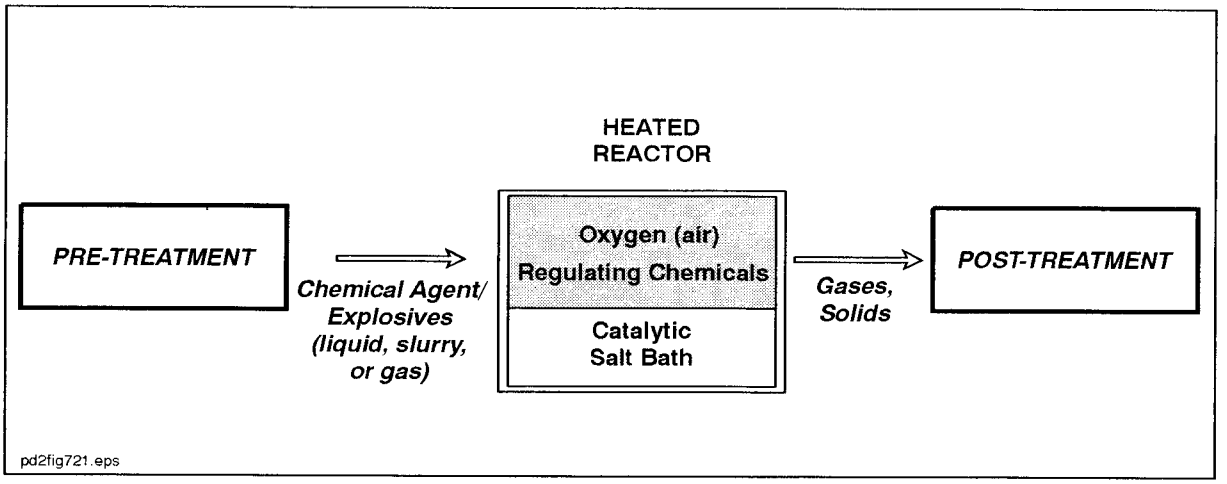

Figure G-18. Illustrative Diagram of Molten Salt Oxidation

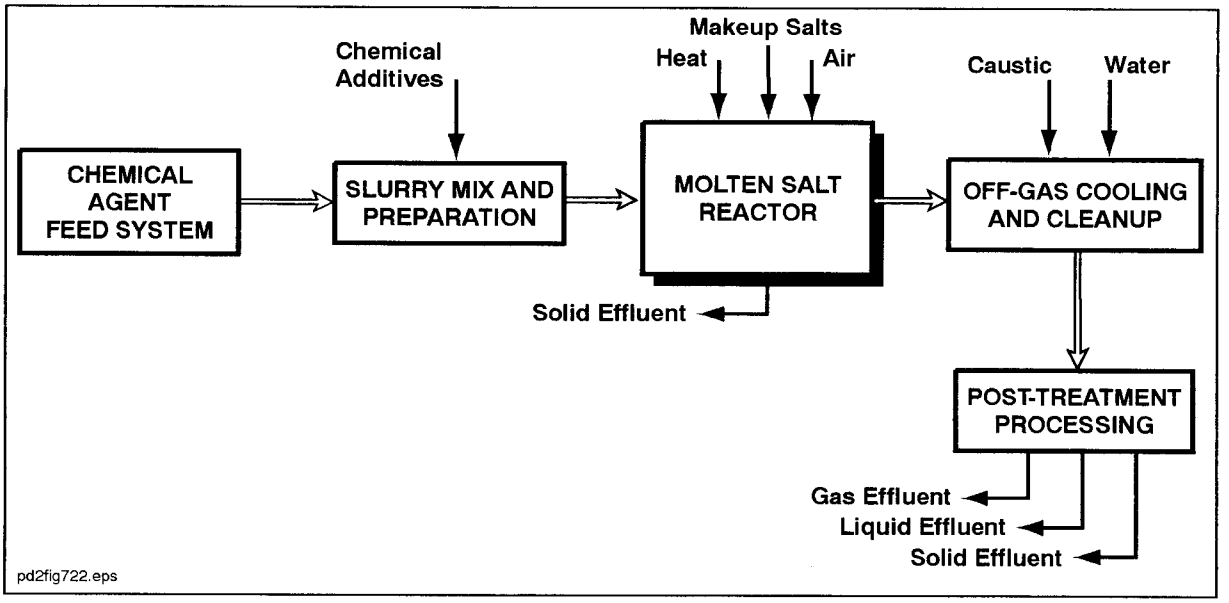

Figure G-19. Process Flow Schematic for Molten Salt Oxidation

The molten salt oxidation process has been used in small-scale (prototype) units to treat the organic portion of radioactive contaminated waste oil, explosives, and propellants. In the laboratory, the treatment of various chemical agents has been demonstrated using molten salt oxidation.

Description

Molten salt oxidation is a process in which organic chemicals undergo thermal decomposition in a catalytic pool of molten salt. Molten salt baths are used commercially for heating and pyrolysis operations. The process uses a molten salt with air to oxidize mixtures of combustible solids, organic liquids, aqueous solutions, or slurries. Salts such as sodium carbonate can be mixed with potassium or lithium carbonate and other additives, to adjust the melting point and performance of the process of the bed media. Acidic by-products (such as hydrogen fluoride, hydrogen chloride, sulfur dioxide, and phosphorous pentoxide) react to form salts that would dissolve in the molten bath. This would result in sodium salts of chlorine, fluorine, phosphorous, arsenic, sulfur, and silicon as well as iron oxide, silver, and copper retained in the molten bed. The process is typically maintained at temperatures from 1,100 to 2,120°F (593 to 1,160°C) using auxiliary heating (NRC, 1993).

The basic process is depicted in Figure G-19. The material to be treated are mixed with any chemical additives and pumped to the refractory (that is, brick-lined vessel) containing the molten salt. Air is introduced to promote mixing and entrain the reactants, and by-products rise through the hot molten salt as bubbles. Maximum solid and slurry particle size are controlled so that they may be carried up through the molten bath. In the molten bath, the agent reacts with sodium carbonate and oxygen from the air to form carbon dioxide, water, and salts that would likely form from the acidic components of mustard or the nerve agent VX. The reaction products of mustard are expected to be carbon dioxide, water, sodium chloride, and sodium sulfate. The reaction products for the nerve agents VX and GB are expected to be carbon dioxide, water, nitrogen, sodium phosphate, sodium sulfate, and sodium fluoride for GB. The carbon dioxide, water, excess oxygen, nitrogen, and some vaporized salts are likely to exit the reactor as off-gas with most of the salts remaining in the reactor (NRC, 1993).

A suitable off-gas system is required to remove particulates, volatilized metals, and any products of incomplete combustion. Very fine salt particles may be formed and carried with the gaseous discharge. Filters are needed to prevent these salt particles and any other particulates from being emitted. No liquid discharge is expected from the molten salt reactor, but treatment of the off-gas generates an aqueous waste stream. The spent salt generated by the molten salt oxidation process is extracted and solidified. As the spent molten salt is removed, fresh sodium carbonate would be added to maintain desirable salt composition. The waste salts are water-soluble and are treated as hazardous waste (Department of the Army, 1994).

Development and Applicability

In 1993, a prototype unit was constructed for the U.S. Department of Energy to test the ability of molten salt oxidation to treat the organic portion of radioactive-contaminated waste oil and simultaneously retain the radionuclides in the salt. Tests using mustard, Lewisite, and GB, and VX were conducted by the Army at the Edgewood Chemical Activity in 1976 (NRC, 1993). Materials tested were GB-contaminated salts, non-diluted chemical agents, and various chemical agent identification sets. Results indicate that soot, char, and chlorine accumulations in the melt need to be controlled to assure efficient molten salt oxidation operation. During tests on mustard agent, small amounts of nitric oxides, organically bound chlorine, and traces of hydrocarbons were found in gas emissions. The process has also reportedly treated explosives and propellants in testing at the Edgewood Chemical Activity and at Lawrence Livermore National Laboratory in California, where pilot testing is being conducted. Several hundred pounds of various energetic materials, including liquid propellants, have reportedly been treated successfully (DoD, 1995).

G.6.1.10 Plasma Arc Furnace

A plasma arc furnace is a static furnace heated by plasma, which forms a molten media in the bottom of the furnace. The reactive environment can be oxidizing, reducing, or steam reforming.

Overview

In plasma processes, energy (usually electricity, but also magnetic fields and microwave radiation can be used as the source of energy) is used to create a reactive zone where chemical compounds are broken down into simple forms (Figure G-20). The energy is introduced into the plasma reactor, in which a preselected gas is added through one or more electrodes causing an arc, or release of energy through the gas in the reactor. This results in the release of heat energy and causes certain compounds in the chamber to become electrically charged, or ionized. Organic compounds injected into this reactive plasma zone are broken down into very small parts (that is, atoms and simple molecules). The gaseous mixture is then cooled and can be mixed with selected gas, steam, or other additives to effect the reforming of chemical compounds as the cooling occurs. Inorganic compounds are melted in the reactor where most are retained until they are removed as a melt during operations.

Oxidation or reduction reactions or a combination of both has been used to treat a variety of organic compounds in the form of a solid, liquid, or gas depending on the particular plasma process. The solid and gaseous by-products from these processes are treated and in some processes, the gas can be burned and used as a fuel. Pilot and laboratory testing has shown that plasma processes are capable of treating many complex organic wastes (for example, polychlorinated biphenyls in a transportable system) and chemicals that are similar to warfare agents and explosive compounds.

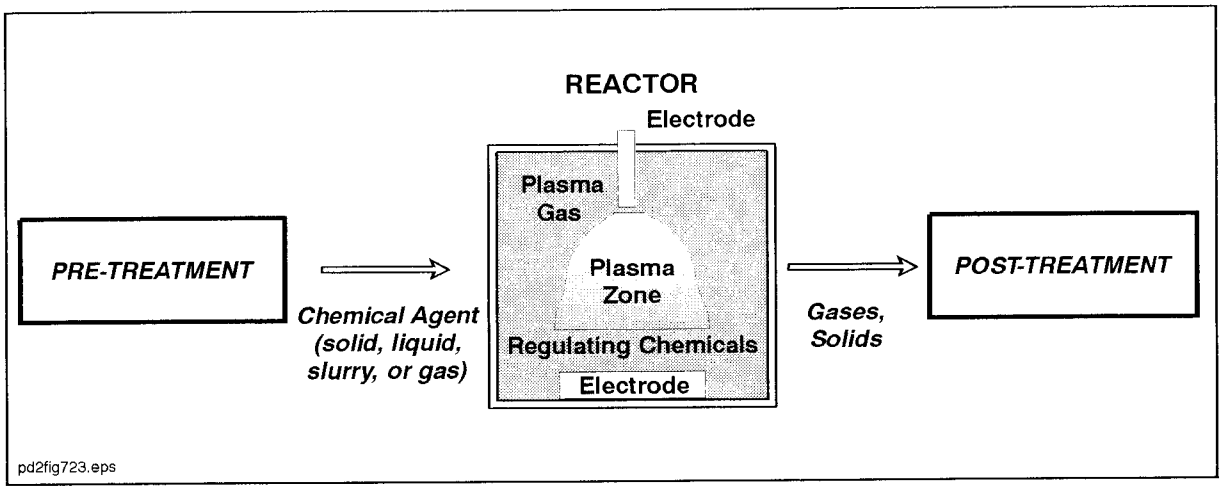

Figure G-20. Illustrative Diagram of Plasma Arc Furnace

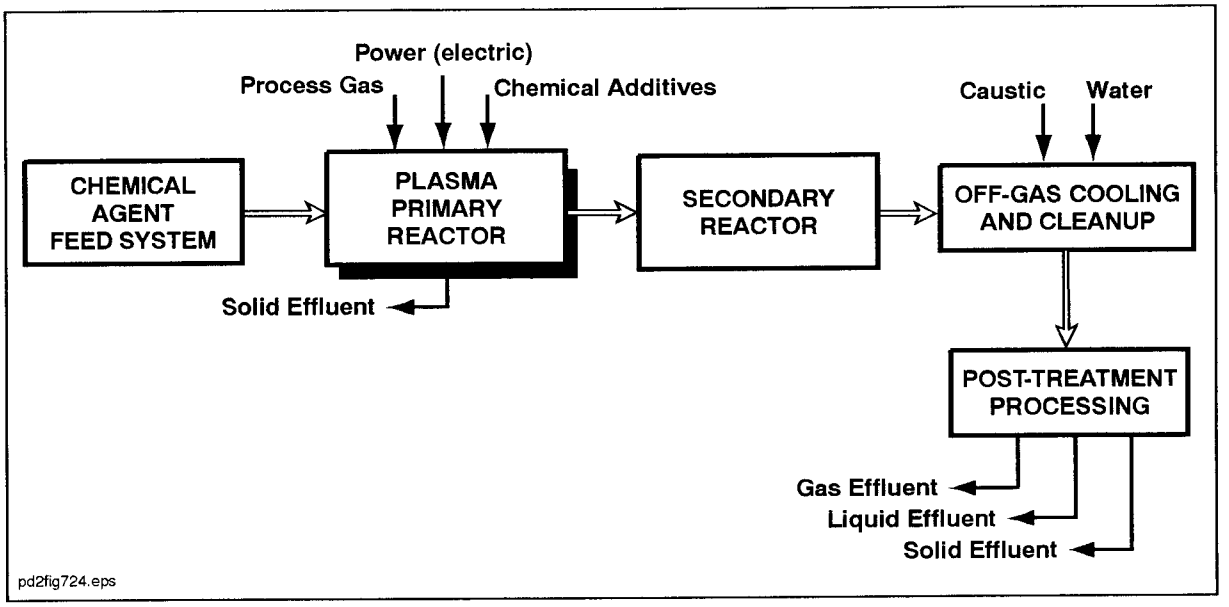

Figure G-21. Process Flow Schematic for Plasma Arc Furnace

Description

In plasma technology, the resistance of a process gas to an induced high activation energy produces a temperature sufficiently elevated to form a plasma torch, arc, or zone of high-energy which consists of atoms, electrons, and charged particles (that is, ions and free radicals). Electric energy is introduced into the system by passing a large current through the process gas using carbon electrodes or by using a molten metal conductive bath as one electrode. In one type of plasma technology, the inductively coupled plasma process, an electric current is passed through a coil surrounding a refractory tube in which the process gas is passed. This results in an oscillating magnetic field that ionizes the plasma gas producing ions, electrons, and free radicals. Although the temperatures near the center of the plasma may reach 30,000°F (16,650°C) or more, the surface of the plasma and surrounding gas temperatures vary between 2,732 and 9,572°F (1,500 and 5,300°C). At these temperatures, the materials being treated are completely pyrolyzed or could be oxidized in the plasma zone by adding a small amount of air or other oxidants (NRC, 1993).

Various plasma reactors of different design, which use oxidizing, reducing, and steam reforming controlled chemical environments, have been developed for treatment of hazardous wastes. Some systems can accept a variety of waste materials including liquids, gases, and/or solids. Plasma torch systems volatilize and decompose organic materials and melt inorganic materials into a glass or ceramic slag, and in some cases, into a molten metal. When withdrawn and cooled, the slag forms a vitrified (glass-like) waste. The molten metal, if formed, can be withdrawn separately. To control viscosity and the characteristics of the molten slag that floats on top of the molten metal inside of the reactor, sand, calcium oxide, or other conditioning chemicals can be added (Department of the Army, 1994).

The basic process utilizing plasma technology is illustrated in Figure G-21. The primary reactor includes the plasma generator and a reaction chamber, which is a refractory-lined vessel. A carrier or process gas (that is, air, oxygen, or non-oxidizing gases such as nitrogen and argon) flows through the plasma generator and becomes a high temperature ionized plasma zone or high temperature thermal plasma. The plasma is electrically neutral with an equal number of positively and negatively charged ions present. Large molecules are broken down chemically into small fragments and ionized. The heat is used in some systems to maintain a molten metal bath, to which the material to be treated is exposed (NRC, 1993).

Typical reaction products from the treatment of chemical agent in a plasma system are expected to include nitrogen, carbon monoxide, hydrogen chloride, hydrogen fluoride, hydrogen, phosphorous pentoxide, hydrogen sulfide, sulfur dioxide, oxygen, and carbon dioxide. Depending on conditions present in the reactor atmosphere, some nitrogen oxides may also form. Salts and some metallic elements will melted or vaporize. Depending on the system design, such materials are recovered in the melt. The gas cooling and cleanup system incorporates design features specific to the particular plasma process employed (NRC, 1993).

Development and Applicability

The plasma technology has been applied to the treatment of various hazardous wastes in laboratory-, pilot-, and commercial-scale applications. A transportable plasma process system to treat liquid wastes that incorporates monitoring, controls, and waste management features has been developed. A system tested at Drexel University laboratories used slurries of a variety of materials including nitroglycerine/nitrocellulose (double-base) propellant in an induction coupled plasma process (DoD, 1995).

Thermal plasma reactions can be carried out under various chemical environments including oxidizing, reducing, and steam reforming environments. Since various plasma gases can be used and the reaction environment can be varied, the chemistry of the reactions taking place and reaction products can be controlled. When air or oxygen is used as the plasma gas, and a steam is added as an oxidant and source of hydrogen, the reactor can produce a fuel or synthesis gas.

G.6.1.11 Steam Reforming

This is a furnace with a steam reforming reactive environment.

Overview

Steam reforming, also referred to as steam gasification, are terms for a general process of forming new compounds from the pieces of organic molecules that are broken apart after introducing superheated steam to a reactor containing the organic substances to be treated (Figure G-22). The process has been used in many different industrial applications for making useful products, and has more recently been tested and used for treating hazardous organic wastes. The process uses heat and steam to control the reactions, but is operated at, or near, normal atmospheric pressures. Most processes using steam reforming include a process step that turns the compound to be treated into gases and vapors before being sent to the reactor where the majority of the chemical reactions take place. Some applications have included the addition of chemicals and catalytic materials to control the reactions and resulting by-products, and to make the process more efficient.

The process has been demonstrated in the laboratory and in small-scale (pilot) testing to be capable of treating several complex and toxic organic compounds, but has not been tested using chemical agents. Waste materials such as paints and epoxies have been treated using commercially available steam reforming systems.

Description

Steam reforming involves high temperature pyrolysis of a vaporized organic feed stream followed by gasification or reforming of gaseous components. The process operates at atmospheric or slightly negative pressures. Figure G-23 depicts the basic steps and process flow. In the evaporator, chemical agent is volatilized using super-heated steam at 600 to 1,300°F (316 to 704°C) in combination with recycled process exhaust gases. Some pyrolysis reactions of

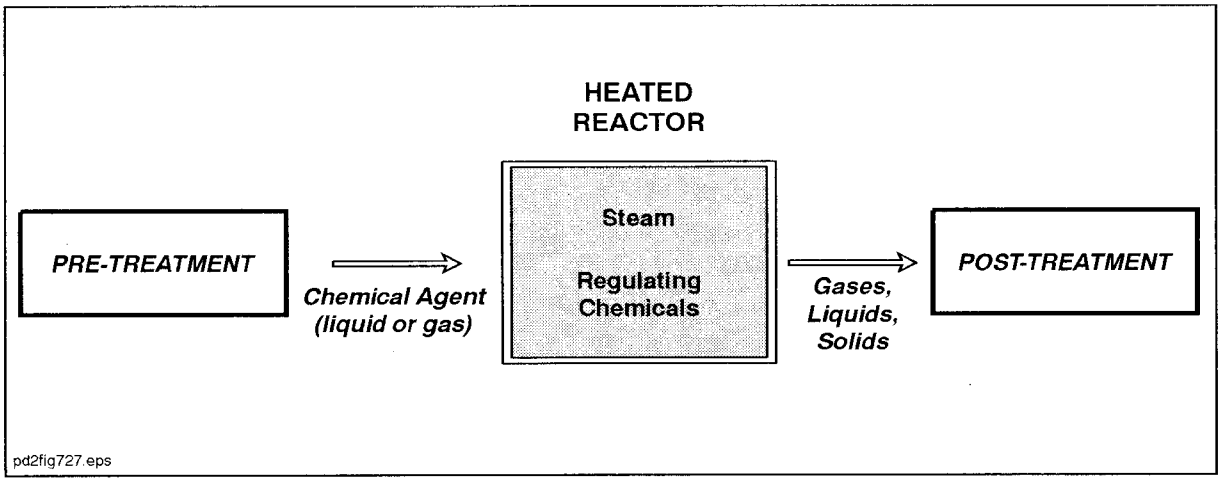

Figure G-22. Illustrative Diagram of Steam Reforming

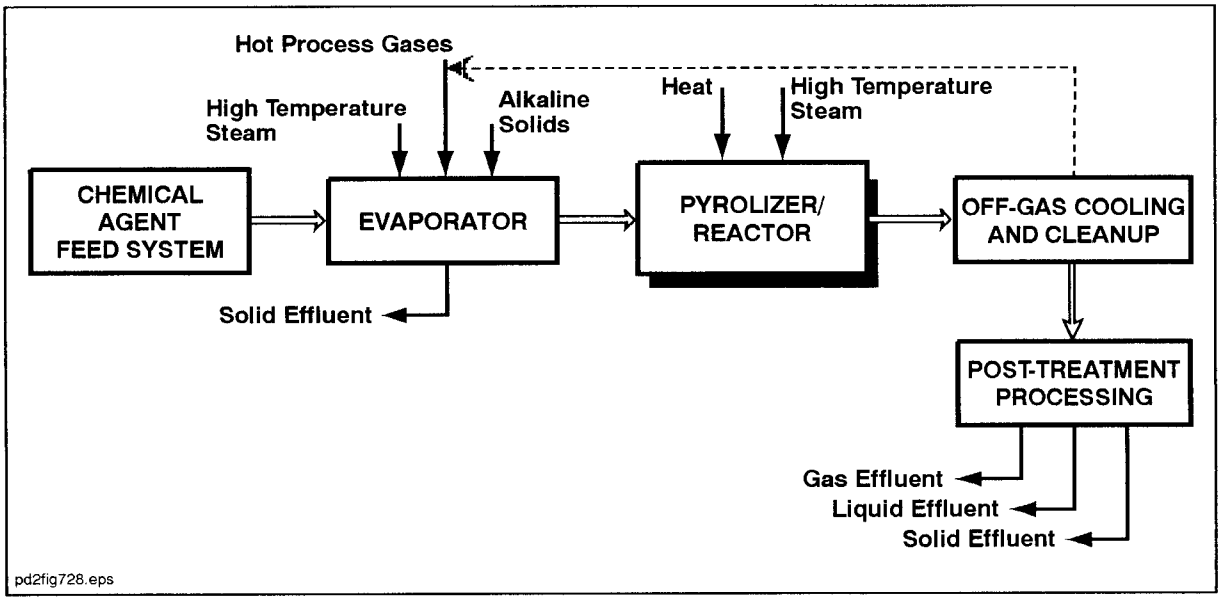

Figure G-23. Process Flow Schematic for Steam Reforming

the volatilized compounds, as well as reactions with the steam, are expected to begin in the evaporator (NRC, 1993).

The evaporator off-gas, which contains concentrations of the initial feed materials as well as steam and products from initial steam reforming reactions, is then processed in the pyrolyzing reactor. In this step, the gases are heated to approximately 2,370°F (1,300°C) to complete the reforming reactions. The process reactions are controlled by the temperature and amount of added steam.

The reactor off-gas, which contains mostly carbon monoxide, hydrogen, and trace quantities of light hydrocarbons such as methane, is passed to the gas stream cleanup and recycle system. Gas cleanup requires treatment steps to remove traces of particulates, acids, and organics. The majority of the process gas could be recycled so that only the small volume being vented from the process requires final processing. Off-gas pollution abatement processing may generate caustic brine, which may be further processed, depending on the effluent.

Treatment of chemical agent is expected to produce carbon monoxide, carbon dioxide, water, hydrogen, hydrogen fluoride, phosphorous acid, methane, nitrogen, and various salts containing sulfite, chloride, fluoride, phosphite, and various low levels of organic compounds, depending on the input materials (NRC, 1993).

Development and Applicability

Steam reforming is a common industrial process that is used to make hydrogen gas from methane using catalysts to control the process reactions. Non-catalytic steam reforming has been studied as a means of gasification of coal and cellulosic wastes. The use of the technology for treating wastes is a relatively new application; however, transportable commercial units using the process have been constructed. The process can also be used to treat off-gas streams from other treatment technologies either by injecting steam into the reaction vessel to reform the gases into different by-products, or treating the off-gas in a separate vessel.

Steam reforming has been demonstrated in bench-scale and pilot testing to successfully treat various organics including carbon tetrachloride, dichlorobenzene, methylene chloride, 1,1,1-trichloroethane, and xylene. Of these compounds, only benzene was reportedly detected at very low levels in airborne emissions from the pollution abatement system. Commercial units have been used in the treatment of spent solvents and waste epoxy, resins, and paints (Department of the Army, 1994).

G.6.2 Chemical

G.6.2.1 Chemical Reagent Digestion/Dissolution

Chemical reagent digestion uses a chemical reagent to digest or dissolve certain materials to both access the internal chemical fills and destroy some chemical fills.

Overview

Chemical reagent dissolution and digestion uses a chemical reagent to dissolve certain materials. Caustic reagents digest aluminum and dissolve and hydrolyze many chemicals, including chemical agents and explosives. Acidic reagents digest metals (except aluminum). Acid digestion represents a process specifically developed for pre-treatment accessing and treatment of CWM, as discussed below (Battelle, 1998).

The acid digestion process involves immersing whole or partial munitions or loose subcomponents in a heated bath of nitric acid under low temperature and slightly below atmospheric pressure (Figure G-24). The nitric acid dissolves munition metal casings and removes and breaks down the chemical agent contained in munitions. Once the metal is dissolved, explosives may dissolve, break into small pieces, or remain whole without the metal casing. The gases, liquids, and solids generated are processed through secondary disposal systems designed to reduce by-products to solid wastes or reusable materials.

The process has been demonstrated on single, full-sized munition. Additional testing on the reaction of nitric acid on the energetic materials and chemical agents has also been conducted.

Description

The acid digestion process depicted in Figure G-25 is the principal disposal element of a two-stage process, one being the acid digestion and the other being the hydrothermal process. Chemical munitions are placed into an acid resistant basket that is put into a munition disposal processing tank. Pre-heated nitric acid (122 to 158°F or 50 to 70°C) flows through the processing tank, covering the munitions. The system is maintained at slightly less than atmospheric pressure. The reaction process is exothermic, but the temperature is controlled by means of a water-cooling jacket. Once the metal is dissolved, some explosives are acted upon by the nitric acid or melt due to the operating temperature. Solid components remaining include aluminum parts, certain paints and potting compounds, and certain explosives. Liquid, solid, and air waste streams are generated.

The second stage process is the hydrothermal process used to destroy the explosives contained in the acid digestion process liquid wastes. This process uses pressurized hot (650°F or 343°C) water and air to treat the explosives. The destruction of the explosives primarily creates carbon dioxide and leaves behind a liquid waste containing nitric acid, water, sodium nitrate, and iron.

Most of the wastes created by the disposal process have components that can be recycled or reused in the acid digestion process. The process has three primary by-products. Two by-products, sodium nitrate and iron, are found in the acid and water solution from the hydrothermal process. This liquid is sent to an evaporator that separates the acid and water from the solid wastes. The nitric acid and water can be reused in the acid digestion process.

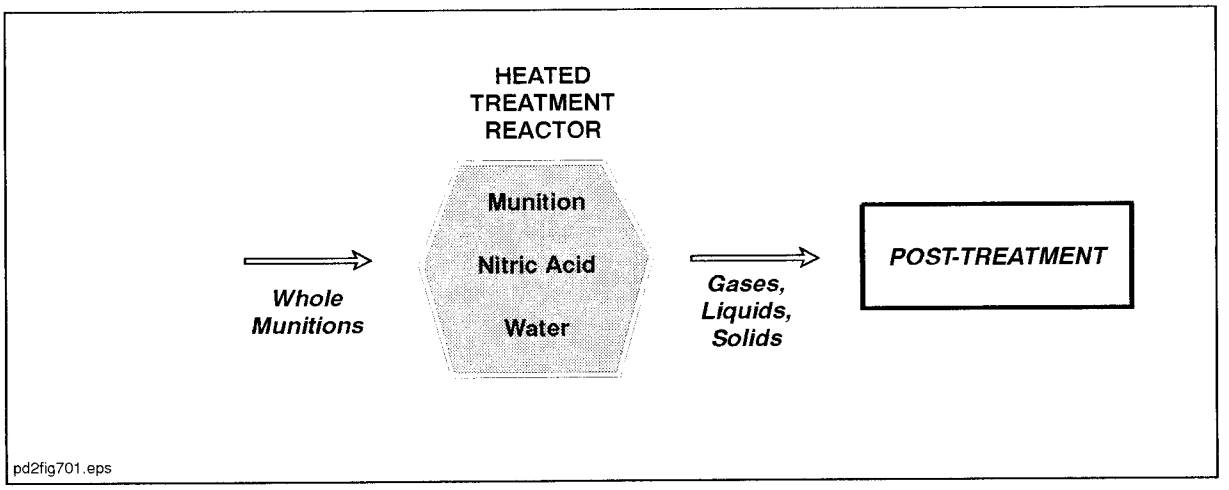

Figure G-24. Illustrative Diagram of Acid Digestion

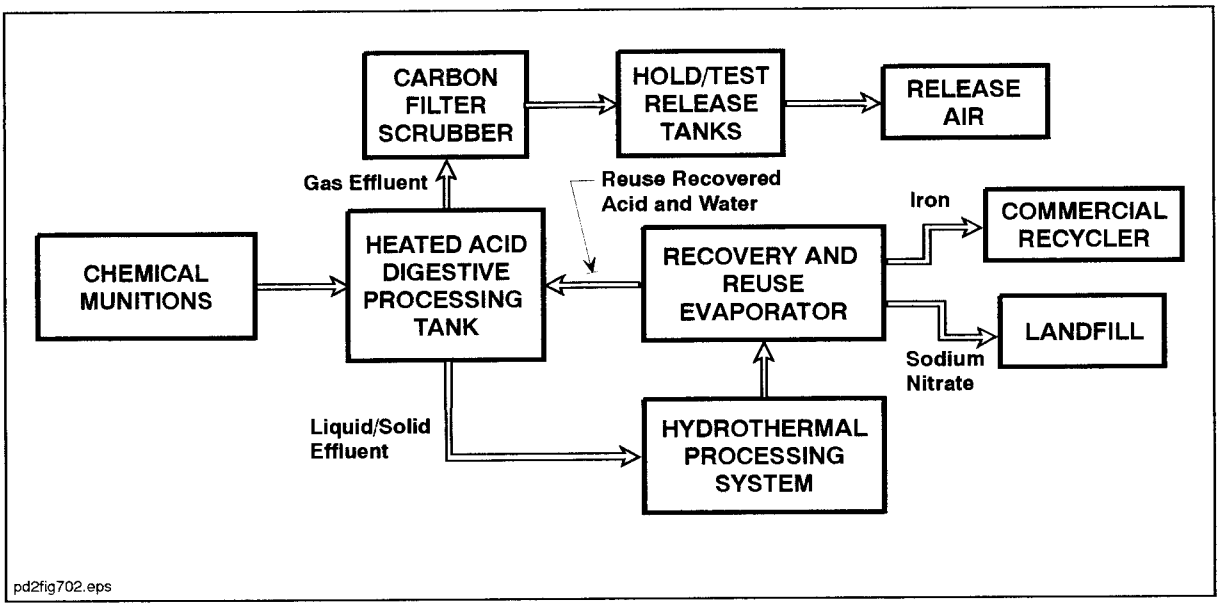

Figure G-25. Process Flow Schematic for Acid Digestion

Once separated, the iron is sent for recycling at a commercial smelter, and the sodium nitrate is packaged for disposal in a landfill.

The acid digestion process creates nitrogen oxides as the third, primary by-product, which are captured by a series of holding tanks after they are passed through a carbon dioxide scrubber. While in the holding tanks, the air can be tested and for agent destruction requirements.

Development and Applicability

The acid digestion process has been demonstrated in bench-scale and pilot testing to assess the viability of using acid solutions to dissolve chemical munitions. Full-scale inert munitions were dissolved in dilute nitric acid at 122 to 158°F (50 to 70°C) in 2 to 4 hours. Reported results indicate that the explosives tested (RDX and TNT) were not sensitized in the digestion process. Other tests were conducted to determine the reaction extent between digestion liquids and the chemical agents mustard, GB, and VX.

G.6.2.2 Chemical Reagent Neutralization

Chemical reagent neutralization uses a chemical reagent to detoxify chemical agent and deactivate explosives.

Overview

Chemical neutralization processes, as many manufacturing processes used extensively in the chemical industry, use the reactive properties of various chemicals that, when mixed together in a solution, change the chemical makeup of the materials to be processed. Neutralizing chemicals, mixed in water or alcohol, have been used for decades by nations around the world to reduce the lethal effects of various chemical agents on the battlefield and at processing facilities. Several different chemicals and techniques have been proposed and tested to treat chemical agents. Many of these processes are relatively simple to carry out and standard chemical processing equipment can be used. The reactions are accomplished at temperatures ranging from room temperature to below the boiling point of water, usually without added pressurization. Although no single chemical treatment has been identified to destroy all agents, the destruction of each type of agent is possible using some kind of chemical neutralization process. The chemical processes that are planned for use in the RRS, MMD and EDS systems are identified in Section 2 and are not repeated in this appendix.

Bleaches, alcohols, and even hot water have been shown to break down certain chemical agents into compounds that can then be further treated using other technologies for complete mineralization. The products resulting from chemical neutralization reactions vary from a relatively uniform mix of simple compounds to a very complicated mix of complex compounds. The chemical reactions may involve a series of sequential reactions that can be affected by additives, impurities, and degradation products of the chemical agent. Chemical neutralization (Figure G-26) can be conducted in mixing vessels of various sizes by adding

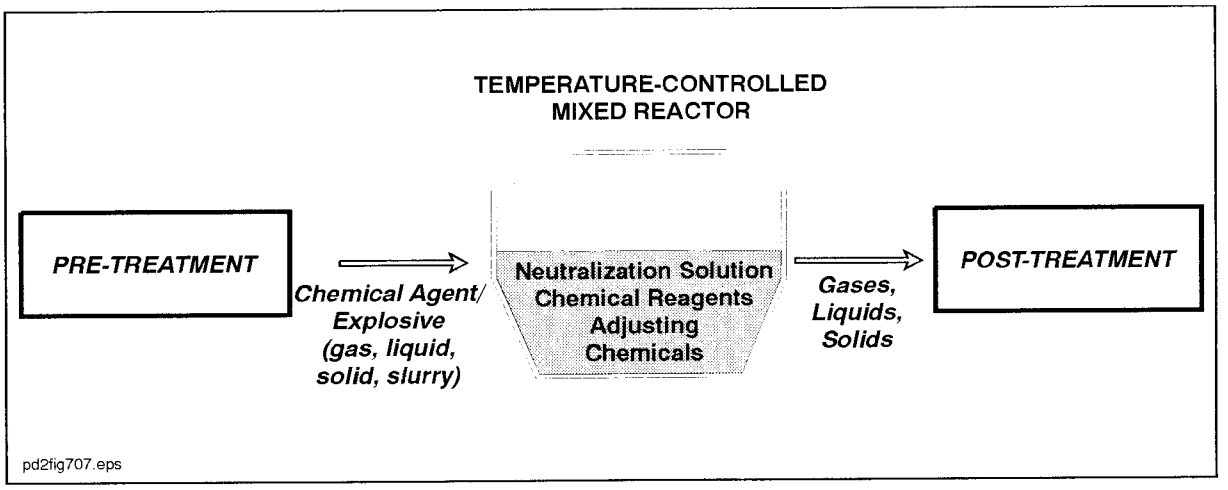

Figure G-26. Illustrative Diagram of Chemical Neutralization

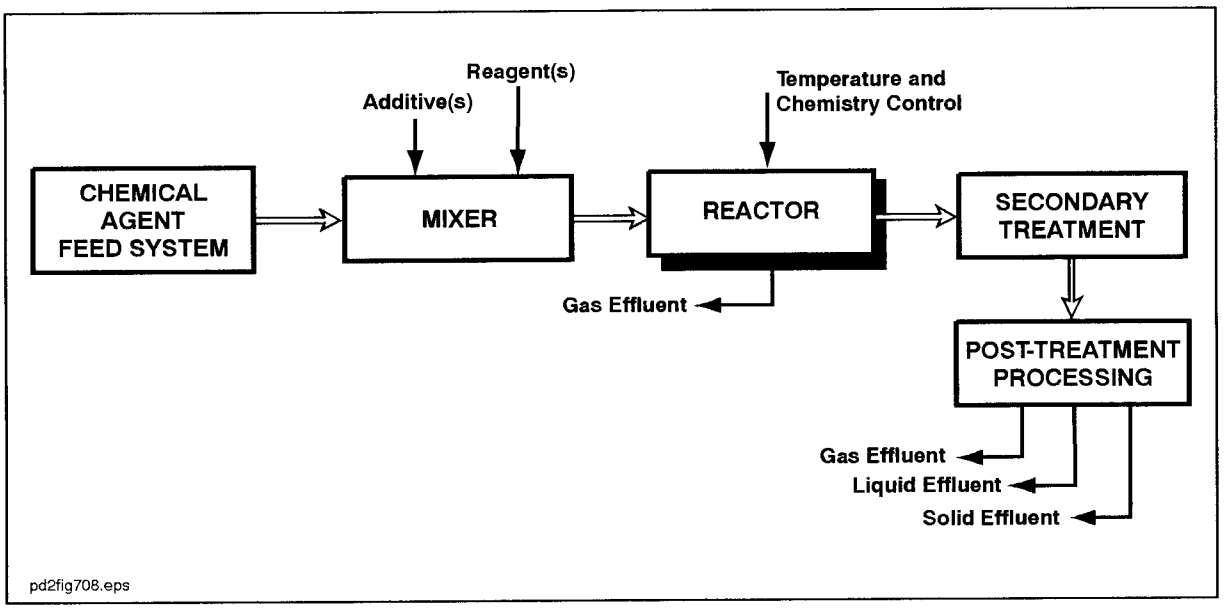

Figure G-27. Process Flow Schematic for Chemical Neutralization

established amounts of chemical agent and neutralization solution, and allowing the reaction to take place. The reaction can be controlled by varying the feed ratios, temperature, and mixing qualities. The reaction waste stream can be held and tested to verify that the reaction completion.

Description

Chemical neutralization alters the chemical and physical properties of the compound being treated and, consequently, often changes the toxicological properties after treatment. A number of chemical processes are known conceptually, experimentally, or in practice to treat chemical agents. Neutralization reactions can be conducted in a batch mode in complete containment, which provides the opportunity to verify the level of chemical agent treatment.

The basic steps in a neutralization process are shown in Figure G-27 and include the following:

- Pre-process and introduce reagents into the feed tanks
- Mix the chemical agent and neutralizing chemicals
- Control mixing, temperature, and reaction times to facilitate effective agent treatment
- Treat process solid, liquid, and gaseous effluents as needed

Many neutralization processes for treatment of chemical agent involve aqueous solutions. For example, hydrolysis (in hot water) has been selected by the Army as the process to be incorporated into a pilot plant at Edgewood Chemical Activity for the treatment of bulk quantities of stockpile mustard. The hot water hydrolysis process consists of vigorous mixing of the sulfur mustard in water at 194°F (90°C) with a water/mustard ratio of 25:1 by weight. Although sulfur mustard is only slightly soluble in water, the carbon-chlorine bonds, which are essential to sulfur mustard's toxicity, react readily in hot water to primarily produce thiodiglycol. Hydrochloric acid is also formed, making the solution highly acidic. Once the reaction is complete, sodium hydroxide is added to adjust the pH level to 12. Experimentation has shown that organic and metal impurities do not interfere with the hydrolysis reaction. The hydrolysate from the process requires further treatment to destroy the thiodiglycol (NRC, 1996).

Other aqueous reagents include the addition of sodium or potassium hydroxides to promote chemical neutralization reactions. The most widely applied method for neutralization of GB has involved caustic (alkaline) hydrolysis. The caustic (sodium hydroxide) chemically reacts with GB to form a sodium organic salt, sodium fluoride, and water. The reaction gives off heat and is rapid. GB decomposes faster as the pH level or temperature increases (NRC, 1993).

The Army has recently selected caustic hydrolysis as the neutralization technique to be used in a pilot plant to treatment of bulk quantities of VX stockpiled at the Newport Chemical Depot in Indiana. The VX/caustic reaction is carried out in an aqueous caustic solution of sodium hydroxide at 194°F (90°C) and ambient pressure conditions. The hydrolysate is then post-treated using supercritical water oxidation to complete the chemical

breakdown into simple compounds such as carbon dioxide, water, and inorganic salts before ultimate disposal.

Chemical agents can be treated in a solution of sodium hydroxide or potassium hydroxide in an alcohol solvent. The solubility of chemical agent in this solution is greater than in an aqueous solution and the volatility of the agent is generally reduced when dissolved in an alcohol-based solvent. In addition, the corrosivity of an alcohol-based system is usually less than a caustic-aqueous solution, thus reducing the corrosion of process equipment. The alcohol may be methanol, 2-methoxyethanol, polyethylene glycol, or ethylene glycol. Laboratory studies show that potassium hydroxide reacts very rapidly with GB to form potassium fluoride, potassium isopropylmethylphosphonate, and water (NRC, 1993).

Development and Applicability

Chemical neutralization has been used for a variety of applications in treating chemical agent worldwide for over 20 years. Caustic hydrolysis has been used extensively by the United States and other nations to treat mustard agents and the G-type nerve agents (for example, GB, Tabun, and Soman). Between 1973 and 1976, the U.S. Army treated 4,188 tons of GB at the Rocky Mountain Arsenal, Colorado, using aqueous sodium hydroxide. The United Kingdom neutralized approximately 18 metric tons (20 tons) of GB using aqueous sodium hydroxide, and the United Nations teams used similar processes to treat about 64 metric tons (70 tons) of Sarin-type agents in Iraq during 1992 and 1993. In Canada during the mid-1970s, mustard agent was hydrolyzed on a production scale (about 7 metric ton batches) with hot lime water prior to incineration. Simple hydrolysis of mustard with hot water has also been used in France and is the basis for the long-used method of steam cleaning and decontaminating storage containers (NRC, 1993).

Chemical systems using other solvents instead of water have also been used. For example, in Poland mustard agents were hydrolyzed on a pilot-scale in a solution of sodium hydroxide dissolved in methanol, followed by incineration. In 1990 and 1991, Canada treated the nerve agents VX, Tabun, Sarin, and other G-type nerve agents by neutralization with a potassium hydroxide and methanol solution, followed by incineration. Ethanolamine has also been used by the United States to neutralize mustard prior to incineration. In the KUASI treatment process, chemical agent is reacted with a chemically active organic solvent at or above 212°F (100°C) for half an hour or more. For mustard and G-type nerve agents, the reagent is ethanolamine. For VX, the reagent mentioned for use in the KUASI system is orthophosphoric acid dissolved in ethylene glycol. In the mid-1980s, the former Soviet Union designed, but never operated, a pilot-scale facility using this process followed by incineration (NRC, 1993).

Chemical treatment processes that involve oxidation have also been tested and used. For example, during the Canadian Swiftsure Project, the oxidizer hydrogen peroxide was used in an aqueous caustic solution to convert Lewisite to 2-chlorovinyl arsine oxide. After the excess hydrogen peroxide was removed, the pH of the reactants was raised under a nitrogen

gas blanket (to reduce the potential for explosion due to generation of acetylene) to convert the arsine oxide to arsenate and chloride salts.

Testing conducted at the Lawrence Livermore National Laboratory used the reactive oxidizing capability of acidified ammonium peroxydisulfate. This strong oxidizing agent is reportedly capable of treating several organic hazardous wastes in solutions from about 160 to 200°F (71 to 93°C), based on laboratory testing. The oxidizing capability of the solution may be enhanced through the formation of hydroxyl radicals and certain intermediate organic free radicals by activation from ultra-violet light, radiolysis, certain metal ion redox couples, or platinum-metal catalysts (NATO, 1994).

G.6.2.3 Mediated Electrochemical Oxidation

Mediated electrochemical oxidation uses electricity to generate a charged metal ion (mediator) in an electrolytic carrier solution to oxidize chemicals.

Overview

Mediated electrochemical treatment uses strong, electrically generated chemical reducing/oxidizing (redox) ions, or mediators, to destroy or synthesize organic substances. Electrochemical treatment has demonstrated successful destruction of a variety of organic substances and treatment of many metallic materials. This treatment uses an electrolytic cell (Figure G-28) to generate the mediators. The organic substance is fed to an aqueous (e.g., acids like nitric or sulfuric) electrolyte solution where a redox ion, or mediator, is continuously produced by the anode of the electrolytic cell. The mediator reacts with the organic substance and is reduced but stays in the electrolyte and can be regenerated by the anode. The ions may react directly to destroy an organic material or may first react with water to form hydroxyl radicals that, in turn, oxidize the material.

Electrochemical oxidation, the more common reaction, produces waste streams that consist of basic oxidation products (gaseous carbon and nitrogen oxides) and sulfates, phosphates and phosphorus pentoxide, nitrates, and chlorides depending on the feed components.

Description

The basic process depicting mediated electrochemical oxidation is illustrated in Figure G-29. In this process, the electrical current generates charged metal ions at the anode which, in turn, react with water and mineral acids in the electrolytic solution to form oxidizing radicals. These radicals react with the organic compound that is added to the cell for treatment. Preparation of separate electrolytic solutions—one for the cathode cell and one for the anode cell—would occur in separate vessels and be fed to the electrochemical reaction cell when needed.

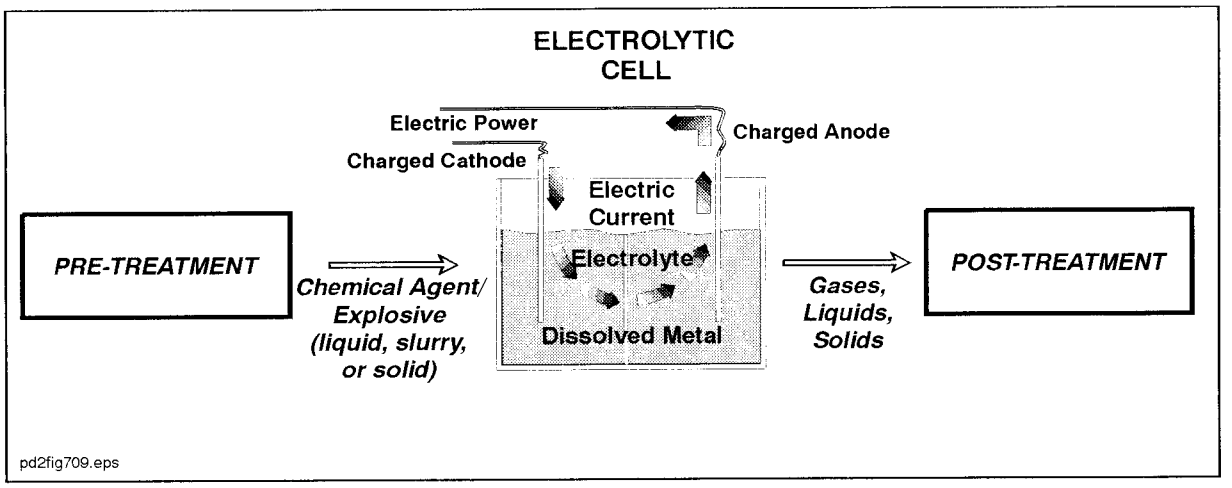

Figure G-28. Illustrative Diagram of Mediated Electrochemical Oxidation

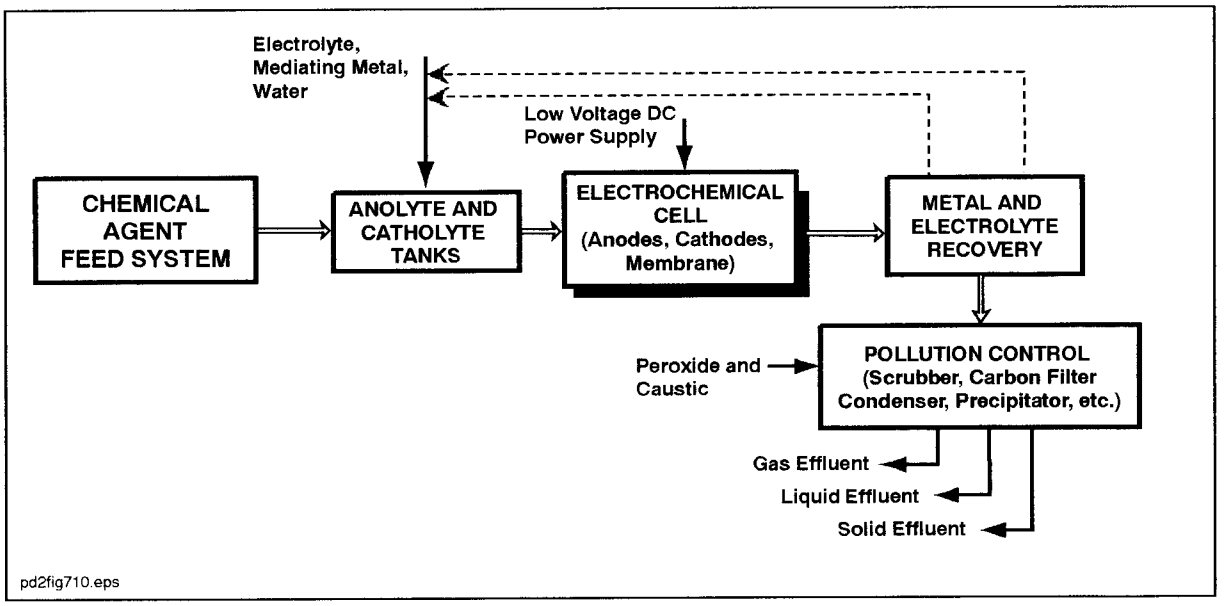

Figure G-29. Process Flow Schematic for Mediated Electrochemical Oxidation

An electrochemical cell with two compartments, the cathode in one compartment and the anode in the other, is separated by a semipermeable membrane. The use of silver as the mediating ion, for example, requires a membrane allowing passage of only certain positively charged silver ions. Alternatively, the oxidizing anode fluid may be pumped to a separate vessel to contact the organic material to be treated. Liquid or slurried organic materials are combined with the solution used in the side of the cell containing the anode and the mediating metal dissolved in the electrolyte. The process generally operates at atmospheric pressure and temperatures of less than 212°F (100°C) (NRC, 1996).

Electrical power is provided as a large current flow at low voltage. The direct current electrical power is distributed to the electrochemical cell, or multiple cell modules, which begins the ion formation and subsequent oxidative reaction. If silver nitrate dissolved in nitric acid is used as the electrolyte, the primary cathode reaction is the reduction of nitric acid to nitrous acid, nitrogen oxides, and water. The electrolyte in the cathode compartment passes through a process to regenerate nitrous acid. The reactive metal ions (for example, silver [Ag^{2+}]) are formed at the anode. If the cell were designed to operate with cobalt dissolved in sulfuric acid, cobalt (Co^{3+}) ions and hydrogen gas would be formed at the cathode (NRC, 1996).

The oxidized solution leaving the cell also contains the mediating metal, which will require separation and recycle. Examples of by-products from this process include a gas stream containing water, hydrogen, nitrogen and nitrogen oxides, carbon dioxide, and carbon monoxide. A liquid stream consisting of brine containing metallic salts and waste acid would also be produced. The process could, however, treat and recycle the mediated metals and the electrolyte, using available industrial techniques to reduce the final waste stream effluent volumes.

Gases require scrubbing to remove any entrained liquids. The off-gas is mixture including principally carbon dioxide, water vapor, oxygen, and nitrogen and nitrogen oxides (especially if nitric acid is used in the cathode cell). Condensate in the vapor of the off-gas requires removal and levels of nitrogen oxides and volatile organic compounds may to be controlled with further post-treatment (Department of the Army, 1996b).

Development and Applicability

Metallic mediators (silver and cobalt) have show successful destruction (oxidation) of a variety of organic materials including many CW agents and energetic materials. The process operates at atmospheric pressure and a temperature of 175-195°F (80-90°C), with reportedly 15 to 20 percent less gaseous waste generated than that from an incinerator. This process still has the capability of destroying organics even at temperatures as low as 70°F (20°C), but this could effect the solubility characteristics of the reaction products (phosphates and sulfates) possibly causing premature precipitation in the reactor. Recently, ruthenium in water has been shown effective.

Oxidation processes using electrochemical cells have been developed for the synthesis of many organic chemicals. Processes have also been developed to carry the oxidation to

completion (for example, hydrocarbon converted to carbon dioxide). Although chemical intermediates are synthesized commercially through direct oxidation, the mediated electrochemical oxidation process has been developed more recently to treat hazardous compounds, including chemical agents and their organic by-products. The mediated electrochemical oxidation process generates reactive positively charged metal ions [for example, silver (Ag^{2+}), cerium (Ce^{3+}), cobalt (Co^{3+}), and iron (Fe^{3+})] from metallic salts dissolved in an electrochemical cell. The ions can react with organic compounds and water to produce carbon dioxide, nitrogen, hydrogen, various inorganic acids, and water. The metal ions may react directly with the organic material to be treated, or may first react with water to form charged ions of hydrogen and oxygen that, in turn, oxidize the material. The four metal ions previously identified have been of greatest interest, but silver is the most reactive (Department of the Army, 1996b).

Atomic Energy Authority Technology (formerly the Atomic Energy Authority of Great Britain) has developed a mediated electrochemical oxidation process employing silver (Ag^{2+}) to treat hazardous materials, including chemical agent. The technology was used in 1987 by Atomic Energy Authority Technology at Dounreay, Scotland, as a means for treating the organic portions of solid and liquid waste streams that also contained low-level radioactive material from the United Kingdom Fast Reactor Fuel Development Program. During 1995, Atomic Energy Authority's Silver II mediated electrochemical oxidation process was evaluated by the Army and the NRC for possible use as an alternative to incineration for the destruction of stockpiles of agent VX at the Newport Chemical Depot, and mustard agent at the Edgewood Chemical Activity. The vendor has indicated that since 1991, laboratory and pilot testing have demonstrated the capability of the process to treat energetic materials (that is, TNT, RDX and certain propellants) and chemical agents (that is, VX, GB, Tabun, and mustard). Treatment of chemical agent was reportedly to levels below analytical detection limits. The electrochemical cells used were similar in design to commercial cells that have been used reliably for decades to manufacture chlorine gas and caustic sodium hydroxide by electrolysis of brine (NRC, 1996).

Pilot tests demonstrating Atomic Energy Authority's Silver II technology used multiple cells that could be monitored and controlled simultaneously. Agent was fed in increments until a specified quantity had been treated. This was followed by sampling to verify the absence of measurable residual agent concentrations indicating that the processing was complete. Mustard agent was converted to mostly carbon dioxide, carbon monoxide, nitrogen oxides, sulfates, nitrates, and chlorides. Agent VX was converted to mostly carbon dioxide, carbon monoxide, nitrogen oxides, sulfates, nitrates, chlorides, phosphates, and phosphorus pentoxide. Hydrogen in the agent was converted to water and chloride was converted to various salts. When treating mustard agent, some silver chloride was produced as a precipitate in nitric acid. This reduces the anolyte concentration of silver that, in turn, decreases the cell efficiency. Therefore, silver chloride must be managed separately during the treatment of mustard (NATO, 1996).

After completion of the operation, the system was emptied and the liquid routed to a process to recover and recycle silver and nitric acid. Several secondary treatment units used in the Silver II process include a nitrogen oxides reformer, silver nitrate recovery, silver management, anolyte off-gas condenser, and off-gas treatment. Insoluble silver chloride is also removed from the system for reclamation of silver (Department of the Army, 1996b; DoD, 1995).

The Army has also evaluated the use of other metal ionic species—for example, cobalt (Co^{3+})—for possible application to treating mustard and VX. A process using cobalt would require changes to the process design discussed for the Silver II process and would result in different reaction products and waste streams. Battelle Laboratories and EO Systems, Incorporated, have been developing a mediated electrochemical oxidation process using cerium as the mediating metal in a nitric acid electrolytic cell (DoD, 1995).

G.6.2.4 Solvated Electron Reduction

Solvated electron reduction uses an alkali earth metal dissolved in an anhydrous carrier solvent to reduce chemicals.

Overview

In solvated electron reduction, organic substances can be added to a solution made up of an anhydrous liquid (no water) containing certain types of reactive atoms such as calcium or sodium, which can result in reduction reactions that break up large compounds into smaller organic molecules and inorganic salts (Figure G-30). The energy released when electrons are detached from the materials in solution is used to break apart the bonds that hold the organic substances together. This reaction occurs rapidly with no added heat, although some reactions require some pressurization to keep the reagent in liquid form. Material to be treated can be added to the reactor in liquid, gaseous, or solid form, and may even be attached to soils or mixed with waste oils. The gaseous and liquid reaction by-products often require further processing for complete mineralization.

This technology has been used to treat polychlorinated biphenyls, in small-scale (pilot) and transportable units and can treat other types of organic compounds including explosives. Various chemical agents have also been treated using this technology in the laboratory.

Description

Solvated electron solutions contain reactive dissociated electrons that bring about a reducing environment that, when mixed with organic substances, have enough energy to break most covalent bonds. These solutions are produced by dissolving alkali or alkaline earth metals (for example, sodium and calcium) in a non-aqueous medium (for example, anhydrous ammonia and oil). The solution can treat chemical agent and other organic compounds to produce smaller organic species and inorganic salts depending on the agent processed.

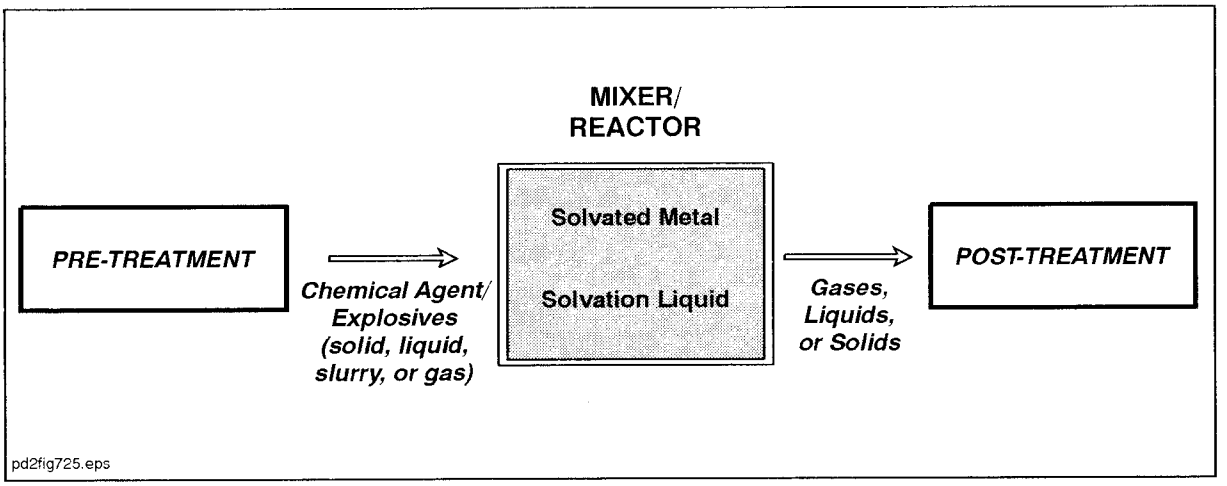

Figure G-30. Illustrative Diagram of Solvated Electron Reduction

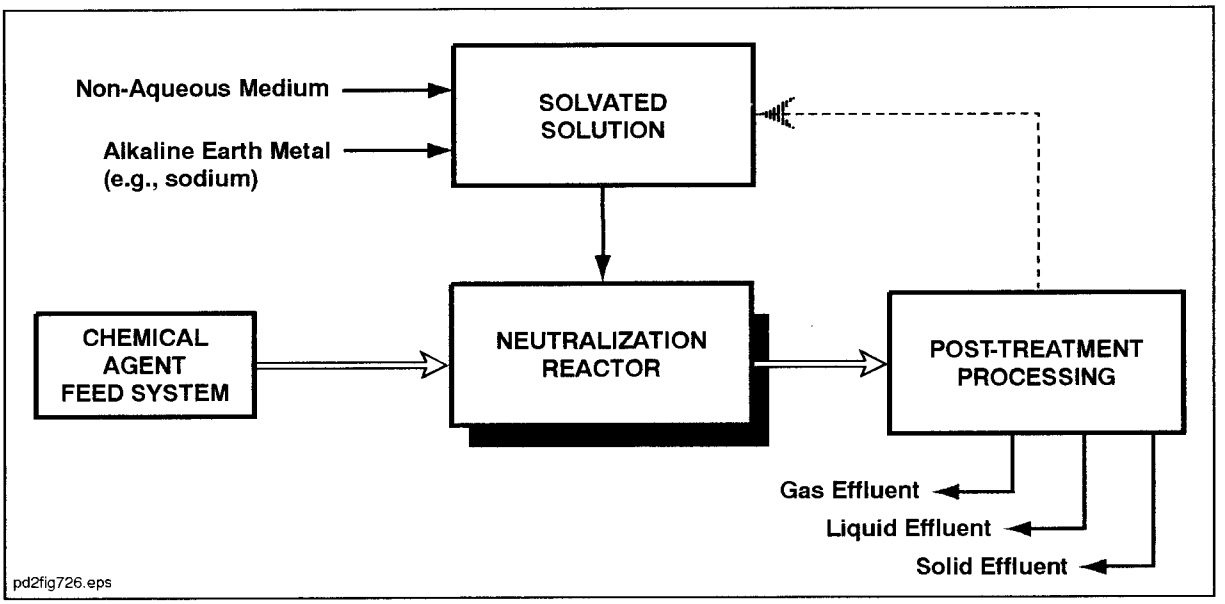

Figure G-31. Process Flow Schematic for Solvated Electron Reduction

The process can be operated at pressures from 0 to about 140 pounds per square inch (1 kilogram per square centimeter) and temperatures from about -28 to 80°F (-33 to 27°C). The reactions liberate heat and occur rapidly without added external energy input. The process can be used to treat materials in solid, liquid, or gaseous form, and different processing rates can be used by scaling the process (Teledyne, 1997; Teledyne, 1998).

The basic process using solvated electron solutions is in Figure G-31 and summarized below.

1. Metallic sodium or other alkaline earth metal is mixed with the non-aqueous liquid (for example, anhydrous ammonia) in a solvator vessel;
2. Toxic wastes/chemical agents are fed into the reactor along with the solvated electron solution;
3. The solvated electrons react with and neutralize the chemical agent or waste materials at a rate controlled by the relative proportions of the feed streams;
4. The newly formed chemical compounds resulting from the reduction reaction are separated from the solution, then further processed as required; and
5. The non-aqueous solution (for example, ammonia) can be recycled.

Development and Applicability

Although the basic chemistry involving solvated electron solutions has been known since the mid-1800s, commercial applications are few. As early as 1865, it was known that if a reactive metal (for example, sodium) were dissolved in anhydrous ammonia, the resulting chemical reaction would occur rapidly and yield free electrons. This is particularly important in the application of treating hazardous materials, particularly those containing halogenated compounds (for example, those with chlorine, fluorine, bromine, or iodine) that have a very strong affinity for free electrons. When organic compounds such as chemical agents are exposed to free electrons, the halogen bonds are broken, destroying the structure of the chemical agent and forming smaller compounds. Reaction products are expected to include: sodium chloride, hydrogen fluoride, and calcium chloride, sodium sulfide, sodium sulfite, sodium amide, sodium arsenate, and various organic and amino salts and water, depending on the feed stream. The off-gas could include various simple hydrocarbons such as ethylene, propane, ethane, or others depending on the application (Teledyne, 1997; Teledyne, 1998).

The solvated electron reduction process has been developed for treatment of hazardous wastes and more recently, chemical agents by Teledyne-Commodore, LLC, which has obtained a patent for a solvated electron technology (SET™) process. This process utilizes metallic sodium dissolved in anhydrous ammonia. The firm has reported that EPA has granted approval for use of the technology to treat polychlorinated biphenyls contained in soils and on miscellaneous metallic materials at its operating plant in Marengo, Ohio, or in transportable units. The firm reports that in addition to the treatment of polychlorinated

biphenyls, the process can treat chlorinated fluorocarbons, spent halogen solvents, pesticides, and chemical agents (Teledyne, 1997; Teledyne, 1998).

Laboratory testing has been conducted using the chemical agents mustard, Lewisite, and the nerve agents GB, Soman, Tabun, and VX. Teledyne-Commodore, LLC, has reportedly tested the process in decontaminating various metal and non-metal surfaces contaminated with chemical agent, and has reportedly successfully treated explosives (nitrocellulose, nitroglycerin, TNT, RDX, and picric acid) in laboratory tests (Teledyne, 1997; Teledyne, 1998).

In Germany, pilot plants using fine sodium particles in a colloidal suspension of oil or coated on a solid granular substrate (for example, aluminum oxide) are used in a reaction column to treat liquid, and dissolved or gaseous wastes such as polychlorinated biphenyl-contaminated oil, and landfill effluents contaminated with chlorinated dioxins, furan, chlorinated phenols, benzene, and hexachlorocyclohexane. The off-gas, mainly hydrogen, is sent through a catalytic treatment system. The liquid effluent, with traces of inorganic compounds and organic impurities, is treated in a final step with ultra-violet irradiation using a high-pressure mercury lamp and hydrogen peroxide as the oxidizing agent (NATO, 1996).

G.6.2.5 Supercritical Water Oxidation

Supercritical water oxidation uses water, heated and pressurized above its supercritical conditions, enriched with oxygen to oxidize chemicals.

Overview

Supercritical water oxidation, also referred to as hydrothermal oxidation, utilizes the characteristics of supercritical water and other chemical compounds when the pressure and temperature of water is increased into the supercritical region (Figure G-32). In this region, the density and composition of vapor and liquid become the same. That is, the temperature is high enough that the vapor can no longer be turned into a liquid, regardless of how much pressure is applied. The solubility of both organic compounds and oxygen is extremely high in supercritical water, greatly increasing oxidation efficiencies and reaction speeds. Conversely, most inorganic compounds (such as metals and salts) generally become relatively insoluble, making them easier to separate from the mixture being treated. The reactions take place in a reactor that is pressurized.

Development of this technology has included design and testing of a transportable unit, and laboratory and field testing of several systems to treat many different hazardous organic chemicals. Several different chemical agents and explosive compounds have been successfully treated in tests using supercritical water oxidation. Although other substances have been studied (for example, hydrogen), water has been used in most supercritical fluid oxidation development applications for treating wastes.

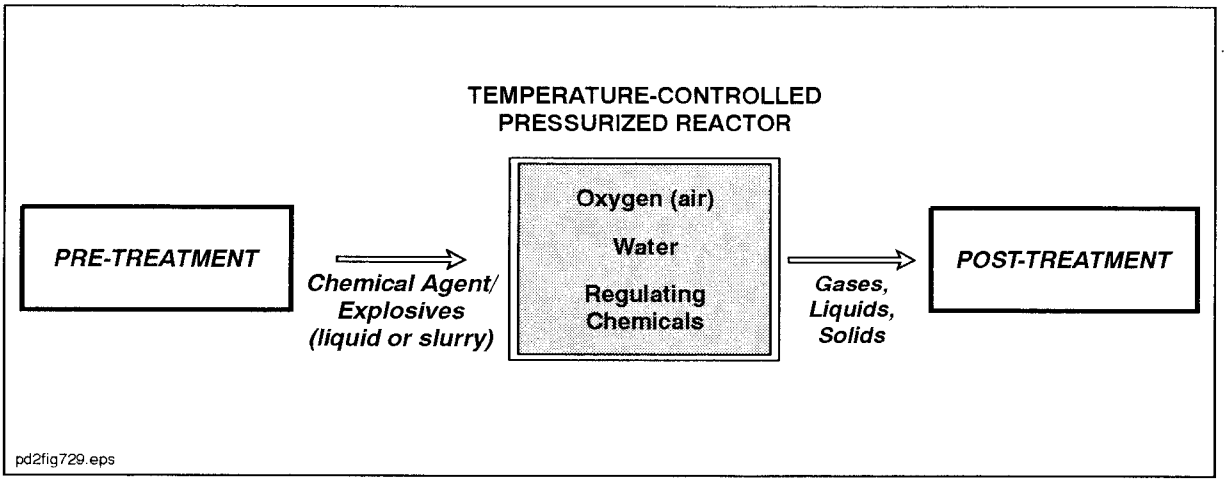

Figure G-32. Illustrative Diagram of Supercritical Water Oxidation

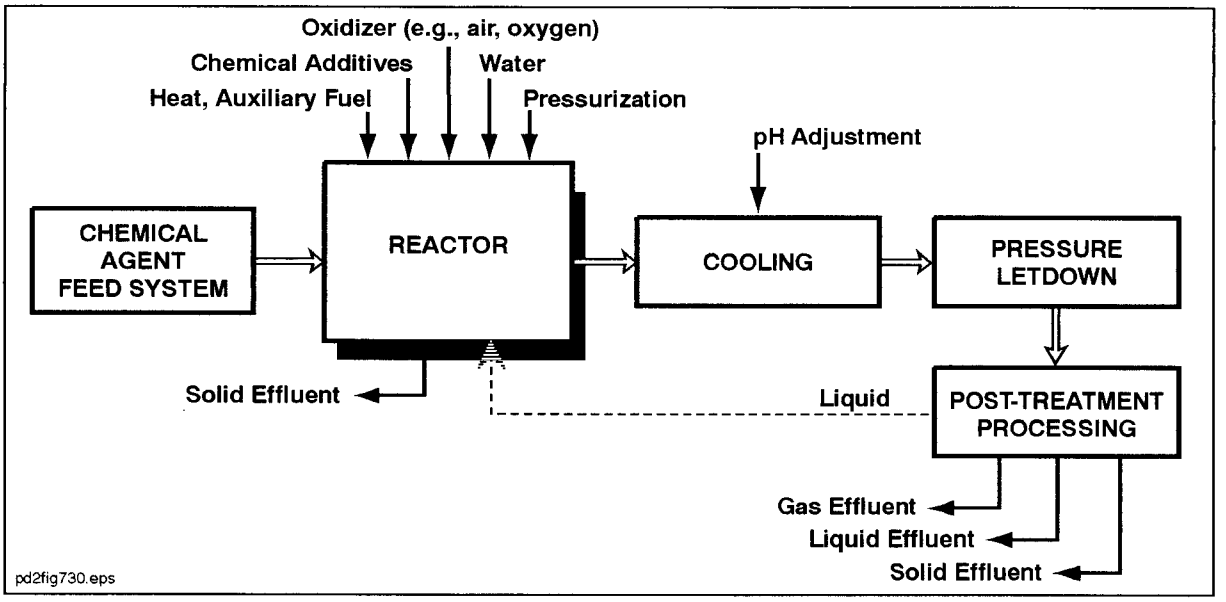

Figure G-33. Process Flow Schematic for Supercritical Water Oxidation

Description

The changes in chemical and physical properties of fluids and gases, as they are indistinguishable when supercritical, can greatly increase normal chemical processing efficiencies. This is due to the solubility changes pointed out above as well as the mixing efficiencies that are gained by avoiding the transfer problems normally associated with phase interfaces (that is, gas-liquid boundary). When oxygen, the supercritical water, and the organic substances to be treated are brought into contact with one another in a reaction vessel, very rapid oxidation reactions occur. In supercritical water oxidation, organic compounds are oxidized above the critical point of pure water (a temperature of 705°F [374°C] and a pressure of 3,205 pounds per square inch [225 kilograms per square centimeter]). At temperatures above 930°F (500°C), high conversions are possible with short (1-minute) reactor-residence times. Hydrocarbons in the waste material to be treated can be converted completely to carbon dioxide and water (NRC, 1993).

Figure G-33 illustrates the general process of supercritical water oxidation. The organic waste materials in an aqueous medium, diluted to about 10 to 20 percent by weight, are compressed from atmospheric pressure to the reactor vessel pressure and injected into the reactor. The process cannot treat liquid agent directly, since it is necessary to dilute the agent to control the highly exothermic reactions as it is being pumped into the reactor. Recycled reactor effluent could also be added. The exothermic reactions provide adequate heat to maintain the reactor at the appropriate temperature. The supercritical water reaction vessel would provide conditions that would allow mixing and high rates of heat transfer that would result in rapid oxidation reactions (NRC, 1993).

Organics are oxidized in the reactor into inorganic salts that have low solubility. The salts are separated from the liquid phase and are collected downstream of the reactor. The gaseous products of reaction, along with the supercritical water, are cooled, depressurized, separated, and processed to meet effluent standards or they are recycled. The off-gas contains primarily carbon dioxide, oxygen, and nitrogen if air is used as the oxidant. In the off-gas stream from treatment of chemical agent, sulfur dioxide, hydrogen fluoride, and phosphorous pentoxide, and low concentrations of methane, nitrogen oxides, and hydrogen have been measured in bench-scale testing (NRC, 1993).

Liquids separated from the reactor effluent during cooling and depressurization would contain salts or brine, which would be processed as the solution is depressurized. The brine from chemical agent treatment may contain hydrochloric, sulfuric, hydrofluoric, and phosphoric acids, depending on the agent being treated, and may need subsequent processing. Following treatment of the brine, liquid effluent could be collected and analyzed, then recycled to the reactor, if necessary. Laboratory tests using chemical agent in supercritical water oxidation yielded low concentrations of acetate, acetone, ammonia, and methylphosphonic acid in the effluent during some of the tests (NRC, 1993).

Development and Applicability

The supercritical water oxidation process has been under active development for over 14 years. Laboratory tests and pilot plants have demonstrated highly successful treatment of many hazardous organic chemicals, including chlorinated hydrocarbons, pesticides, and surrogate compounds for chemical agents. Federal agencies such as the Army Research Office, U.S. Department of Energy, the National Science Foundation, the National Aeronautics and Space Administration, and the Advanced Research Projects Agency have researched this technology. Numerous waste compound studies have the objective of demonstrating complete oxidation with no products of incomplete combustion remaining in solution. Development activities are also focusing on how to handle the problem of acid formation in the reactor, which could result in severe corrosion of the equipment. Several patents have also been issued utilizing this process and related equipment development (DoD, 1995).

Bench-scale testing for the Advanced Research Projects Agency and the Air Force has been conducted using dilute VX, GB, and mustard, and on the propellants CYH and DDP (containing nitroglycerin, nitrocellulose, HMX explosive, and ammonium perchlorate). The propellants were first hydrolyzed in ammonium hydroxide and then treated in a supercritical water oxidation test reactor. The total organic content of the process stream was reduced by 99.9 percent in some test conditions. A skid-mounted pilot plant designed to be transportable has been designed for demonstrating treatment of organic wastes such as chemical agent, propellant, and other waste materials. A separate prototype unit designed to process up to about 800 pounds (360 kilograms) of propellant per day has also been constructed and has received a research and development permit to operate (DoD, 1995).

G.6.2.6 Wet Air Oxidation

Wet air oxidation uses water, heated and pressurized below its supercritical conditions, enriched with oxygen to oxidize chemicals.

Overview

Wet air oxidation processes use high temperatures and pressures to break down large organic compounds into smaller molecules similar to supercritical oxidation processes, except that the reactions occur below the supercritical region (Figure G-34). This also results in different reactions and different by-products in the liquids and gases. Wet air oxidation has been used in various industrial processes for decades, including treatment of waste compounds. The input material is usually diluted in water as a means of controlling reaction rates and temperatures.

Although treatment of chemical agents has not been tested using this technology, treatment of pesticides, which are similar to agents, has been shown to reduce the waste material to simpler compounds. The gases, liquids, and salts resulting from this process must be treated further to reduce problems of handling and disposal.

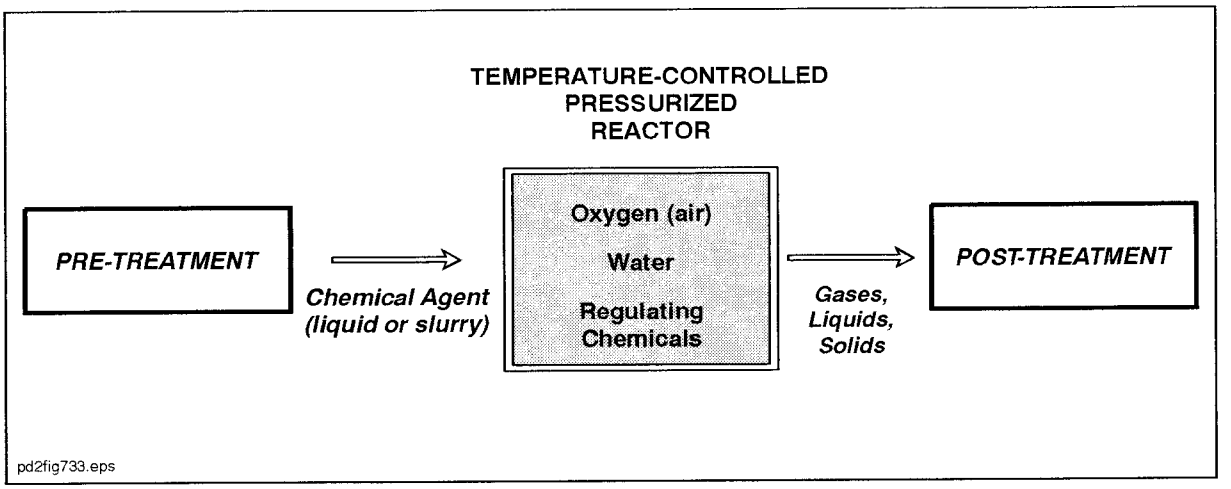

Figure G-34. Illustrative Diagram of Wet Air Oxidation

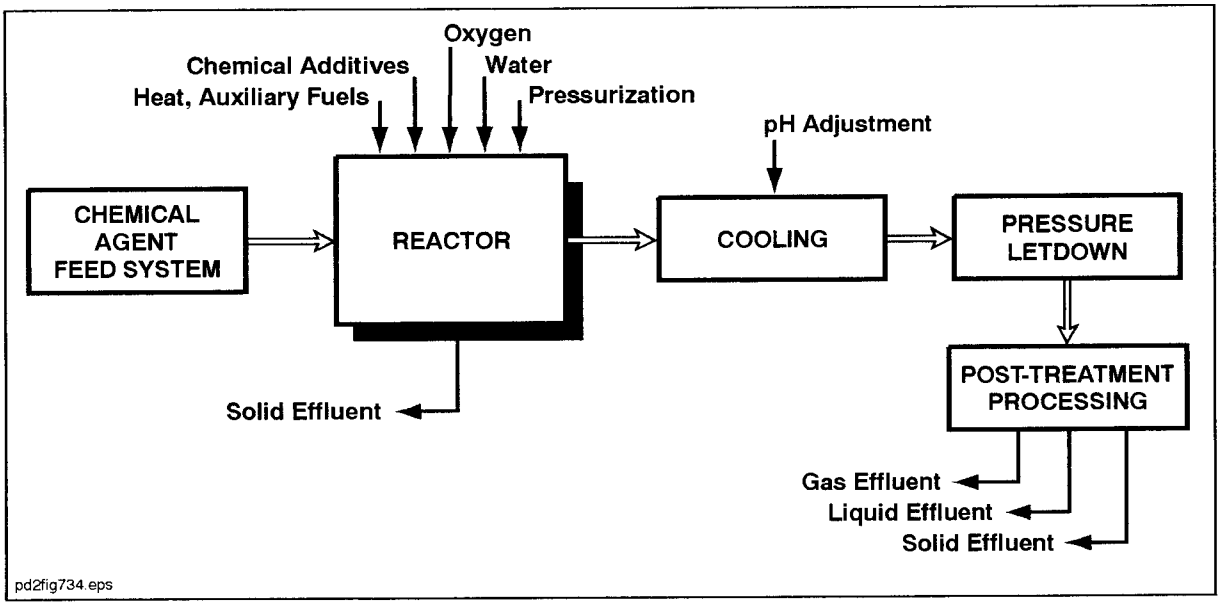

Figure G-35. Process Flow Schematic for Wet Air Oxidation

Description

Wet air oxidation is an aqueous-phase process using molecular oxygen to oxidize dissolved or suspended substances in an environment of elevated pressure and temperature. The usual temperature range is 300-600°F (149-316°C) with pressures up to 2,000 pounds per square inch (141 kilograms per square centimeter). In the wet air oxidation process, large organic molecules broken into smaller organic compounds that oxidize much more slowly, and may even remain in the reactor effluent requiring follow-on treatment. The rate of oxidation and the remaining percentage of organic molecules depend on temperature and pressure (NRC, 1993).

The wet air oxidation process is capable of a high degree of conversion of toxic organics. However, most materials are not oxidized completely (for example, to carbon dioxide and water). Instead, the reaction proceeds through a series of intermediate compounds and some of these are slow to oxidize further. For example, small carboxylic acids, such as acetic acid, remain in solution and may represent up to 25 percent of the original weight of the organic (NATO, 1996).

In wet air oxidation, air or another oxidant is mixed with an aqueous feed mixture and compressed to the required pressure inside the reactor vessel. The basic process steps are depicted in Figure G-35. External heat or auxiliary organic fuel, and any chemical additives used for pH control or to improve reaction performance are added as needed. Heat is released in the reactor as the materials being treated are oxidized, which increases the reactor temperature further. The amount of heat added, and the amount of reaction heat used, will depend on the concentration and caloric value of the organics in the water. Higher concentrations of organic matter release more heat and lead to a greater temperature rise in the reactor.

Organic compounds with carbon, hydrogen, nitrogen, and oxygen are converted to carbon dioxide, carbon monoxide, nitrogen, water, and low-molecular compounds such as acetic acid. Volatile organic compounds present in the off-gas require treatment before being vented from the system. The other components of the material being treated determine the off-gas and liquid effluent constituencies. For example, compounds containing sulfur convert to the sulfate ion (SO_4^{2-}), and the phosphate ion (PO_4^{3-}) results from a phosphorous-bearing compounds. Similarly, chlorine converts to the chloride ion (Cl^-), and nitrogen converts to the ammonium ion (NH_4^+), nitrogen, nitrate ion (NO_3^-), and nitrous oxide. The waste streams may require subsequent treatment, as appropriate, for discharge from the system (NRC, 1993).

Development and Applicability

Patents on wet air oxidation date back to 1911, however, industrial application has occurred mainly in the last 25 years. More than 200 plants utilizing wet air oxidation are operating worldwide. A variety of materials have been treated with this technology, including spent caustics, sludge in municipal and industrial wastewater treatment, wastewater

from chemical production processes, and pulp and paper plant wastes. The process has been applied to pesticides with chemical structures similar to those of nerve agents. In all of these applications, organic and inorganic compounds were reportedly converted to simple products (NATO, 1996).

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Appendix H

Chemical Weapons Convention

The *Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on Their Destruction*, commonly referred to as the Chemical Weapons Convention (CWC), was signed on January 13, 1993, by over 150 nations, including the United States. The Chemical Weapons Convention was ratified by the U.S. Senate on April 25, 1997 and entered into force on April 29, 1997.

The CWC requires the United States to destroy all of its chemical weapons and chemical weapon production facilities under the observation of an international organization called the Organization for the Prohibition of Chemical Weapons. Specifically, the CWC bans the use, development, production, acquisition, stockpiling, retention, and direct or indirect transfer of chemical weapons. The United States must declare and destroy its chemical weapons in accordance with the provisions of the CWC. Discussed below are some aspects of the CWC that apply to non-stockpile chemical warfare material considered in this environmental impact statement.

H.1 Schedule of Chemicals

The CWC divides chemicals into three schedules with varying restrictions on each (Table H-1). Schedule 1 chemicals are the most dangerous; their production is limited by the provisions of the CWC and is subject to inspections and monitoring with on-site instruments. This category includes agents such as Sarin (GB), VX (a nerve agent), and mustard gas (HD). Schedule 2 chemicals have limited commercial utility, and because they can easily be converted to chemical weapons, are tightly restricted. Production of these chemicals above CWC limits is subject to reporting and verification through on-site inspections; examples include BZ (an incapacitating agent) and Amitón (an insecticide). Schedule 3 chemicals are former chemical weapon agents (blood/choking agents), precursors, or chemicals of a toxicity that could threaten the goals of the CWC, but are also used in large commercial quantities. Restrictions on Schedule 3 are similar to Schedule 2, but threshold limits are higher. Examples include phosgene and hydrogen cyanide. See Table H-2 for the schedules of chemicals likely to be encountered during the non-stockpile program.

H.2 Chemical Weapon Declarations

The CWC requires each state party to declare the precise location, aggregate quantity and detailed inventory of chemical weapons it owns or possesses, or that are located in any place under its jurisdiction or control. The declaration must be made not later than 30 days after the CWC enters into force.

Table H-1. Guidelines for Schedules of Chemicals[1]

Schedule	Guidelines
1	• It has been developed, produced, stockpiled, or used as a chemical weapon. • It poses a high risk to the object and purpose of the Convention by virtue of its high potential for use in activities prohibited under the Convention. • It possesses such lethal or incapacitating toxicity as well as other properties that would enable it to be used as a chemical weapon. • It maybe used as a precursor in the final stage technology of a toxic chemical listed as Schedule 1. • It has little or no purposes not prohibited under the convention.
2	• It poses a significant risk to the object and purpose of the because it possesses such lethal or incapacitating toxicity as well as other properties that could enable it to be used as a chemical weapon. • It maybe used as a precursor in the final stage technology of a toxic chemical listed as Schedule 1 or Schedule 2. • It poses a significant risk to the object and purpose of the Convention by virtue of its importance in the production of a chemical listed in Schedule 1 or Schedule 2. • It is not produced in large commercial quantities for purposes not prohibited under the Convention.
3	• It has been produced, stockpiled, or used as a chemical weapon. • It poses otherwise a risk to the object and purpose of the Convention because it possesses such lethal or incapacitating toxicity as well as other properties that might enable it to be used as a chemical weapon. • It poses a risk to the object and purpose of the Convention by virtue of its importance in the production of one or more chemicals listed in Schedule 1 or Schedule 2. • It may be produced in large commercial quantities for purposes not prohibited under the Convention.

Chemical weapons buried on its territory before 1 January 1977 or which had been dumped at sea before 1 January 1985 do not need to be declared unless they have been recovered. Buried chemical weapons that are recovered after the CWC is already in effect must be declared within 180 days of its discovery.

H.3 Order of Destruction

The CWC outlines the order of destruction of specified categories of declared chemical weapons and requires that their destruction be completed not later than ten years after the Convention enters into force. This timetable for the United States is shown in Table H-3. Buried chemical weapons recovered and declared after the CWC enters into force must be destroyed as soon as possible.

[1] CWC, Annex of Chemicals, Part A.

Table H-2. Overview of Chemical Warfare Agents and Industrial Chemicals that could be Encountered During the Non-Stockpile Chemical Materiel Project

Designation	Chemical	Use	State	CWC Schedule[a]
Chemical Warfare Agents				
H	Levinstein mustard	Blistering agent	Oily liquid	1
HD	Mustard-distilled	Blistering agent	Oily liquid	1
HL	Mustard-lewisite mixture	Blistering agent	Oily liquid	1
HT	Mustard-T mixture	Blistering agent	Liquid	1
HN-1	Nitrogen mustard 1	Blistering agent	Oily liquid	1
HN-2	Nitrogen mustard 2	Blistering agent	Oily liquid	1
HN-3	Nitrogen mustard 3	Blistering agent	Liquid	1
L	Lewisite	Blistering agent	Oily liquid	1
GB	Sarin	Nerve agent	Liquid	1
GD	Soman	Nerve agent	Liquid	1
GA	Tabun	Nerve agent	Liquid	1
VX	VX	Nerve agent	Liquid	1
Industrial Chemicals[b,c]				
DM	Adamsite	Vomiting agent	Crystalline solid	N/A
CA or BBC	Bromobenzyl cyanide	Tearing agent	Solid or liquid	N/A
CN	Chloroacetophenone	Tearing agent	Powder	N/A
CNB	Chloroacetophenone in benzene and carbon tetrachloride	Tearing agent	Liquid	N/A
CNS	Chloroacetophenone and chloropicrin in chloroform	Tearing and vomiting agent	Liquid	3
PS	Chloropicrin	Tearing and vomiting agent	Oily liquid	3
CK	Cyanogen chloride	Blood agent	Liquid	3
DP	Disphosgene	Choking agent	Oily liquid	N/A
AC	Hydrogen cyanide	Blood agent	Liquid	3
CG	Phosgene	Choking agent	Gas	3
BZ	3-quinuclidinyl benzilate	Incapacitating agent	Crystalline solid	2
GA simulant	Ethyl malonate	Chemical agent simulant	Liquid	N/A
CG simulant	Triphosgene	Chemical agent simulant	Crystalline solid	N/A

CWC – Chemical Weapons Convention.

[a]CWC, Annex of Chemicals, Part A. Chemicals marked with N/A will be classified based on guidelines in Table H-1.

[b]Chemical agents are sometimes mixed with chlorobenzene and nitrobenzene.

[c]Chloroform occurs as a solvent in CAIS items.

Table H-3. Destruction Timetable for U.S. Chemical Weapons

Category	Description	Timetable
1	Chemical weapons filled with Schedule 1 chemicals	Phase 1: 1% destroyed by April 2000 Phase 2: 20% destroyed by April 2002 Phase 3: 45% destroyed by April 2004 Phase 4: 100% destroyed by April 2007
2	Chemical weapons filled with any other chemicals	100% destroyed by April 2002
3	Unfilled munitions, devices, and equipment specifically designed for use directly in connection with employment of chemical weapons	100% destroyed by April 2002

H.4 Extension of the Deadline for Completion of Destruction

If a state party believes that it will be unable to complete the destruction of Category 1 chemical weapons not later that 10 years after the entry into force of the Convention, it may submit a request to the Executive Council for an extension of the deadline[2]. The request shall contain the duration of the proposed extension, an explanation of the reasons of the extension, and a plan for destruction during the proposed extension and the remaining portion of the original 10-year period. The request for an extension must be made no later than nine years after the entry into force of the convention and in no case shall extend beyond 15 years after the entry into force of the convention.

H.5 Verification

Verification of the destruction of the chemical weapons will be conducted by an inspection team assigned by the Technical Secretariat. The initial inspection will be done to verify the accuracy of the relevant declaration. Following the initial inspection, systematic verifications of the destruction of chemical weapons will be conducted to confirm the identity and quantity of chemical weapons to be destroyed and that these weapons have been destroyed.

H.6 Exemptions from Verification of the Destruction of Chemical Weapons

Several items that may be recovered from burial areas can be exempt from the destruction verification process and be treated as toxic waste as opposed to chemical weapons.

[2] CWC, Article IV, Paragraphs 24–28.

H.6.1 Chemical Agent Identification Sets (CAIS)

CAIS were produced as training kits in aiding soldiers in identifying and defending against chemical attacks. Since the CAIS were not produced to be used as a munitions, they are not classified as chemical weapons under the convention and therefore may be treated as toxic waste in accordance with national legislation.

H.6.2 Old Chemical Weapons

Chemical weapons that were produced before 1925 or chemical weapons produced in the period between 1925 and 1946 that have deteriorated to such extent that they can no longer be used as chemical weapons are classified as old chemical weapons.[3] Old chemical weapons, as confirmed by the Technical Secretariat, are not subject to the destruction verification and may be treated as toxic waste in accordance with national legislation.[4]

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[3] CWC, Article II, Paragraph 5.

[4] CWC, Verification Annex, Part IV (B), Paragraph 6.