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# A HISTORY OF WASTE DISPOSAL AT TECHNICAL AREA 21

1943-1978

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## 2.1 BACKGROUND

### 2.1.1 History of Waste Disposal at TA-21 (1943-1978)

#### A. Introduction

During World War II, Los Alamos National Laboratory was established and given the responsibility for the research, development, and testing of the first deliverable nuclear device. In order to achieve this goal, much research was required to establish the chemical and metallurgical properties of the nuclear material necessary to achieve and sustain the required nuclear fission reaction. Consequently, the Chemistry Division was created in 1943 and given the responsibility of purifying the plutonium received from other national laboratories. The plutonium-bearing residues created in these research and development efforts were extremely varied in type of contaminant as well as in the nature of residue. The recovery and purification of these residues required, therefore, the use of a number of processes. As a consequence, the waste streams generated are often unique to the processes that produce them and often require a specific treatment and disposal technique. Thus, it is the scope of this section to discuss the waste management practices as well as to highlight the plutonium recovery processes and the chemicals used in these processes at TA-21 from the early 1940's to 1978 when plutonium processing operations were moved to TA-55.

#### B. Process Characterization

By September 1944, the Chemistry Division had developed several separatory techniques which allowed the recovery and concentration of plutonium from purification residues so that the plutonium could be recycled. By September 1945, after the chemistry of plutonium had become better understood and the tolerances for light-element impurities in plutonium metal

were relaxed, the researchers in the Chemistry Division began to develop new separatory techniques which not only eliminated several reactionary steps, but also decreased the raw chemical requirement, thus decreasing the total volume of liquid waste generated.

The design of the DP Site West plutonium purification facilities was based on a separation process which used a double plutonium trioxalate precipitation, a sodium plutonyl acetate precipitation and a double ethyl ether extraction. Improved processes eliminated a plutonium trioxalate precipitation and the sodium plutonyl acetate precipitation, and as the purity of the incoming material increased, it was found that only a single acetate precipitation was required to achieve the necessary purity in the plutonium metal. This allowed the chemists to eliminate the acetate precipitations and ethyl ether extraction processes. Once the plutonium had been converted to the oxalate form, it was then converted to the tetrafluoride form (Christensen and Maraman, 1969).

Prior to fluorination, the plutonium solutions underwent several hydroxide precipitation and dissolution steps. During the hydroxide precipitation steps, a supernatant containing approximately $10^{-5}$ g/L Pu was produced and discarded (Christensen and Maraman, 1969). It is believed that these waste streams were stored in the "General's Tanks" at Material Disposal Area A. Other processing operations produced supernatant solutions which contained iron, potassium, sulfates, nitrates, phosphates, chloride, iodine, bromine, and carbon dioxide, all containing traces of plutonium and all of which were discarded. It should be noted that during the early 1940's, the acceptable discharge concentration for plutonium was $10^{-4}$ g/L (Christensen and Maraman, 1969).

The processes selected for the purification of plutonium produced only a percentage of the total waste volume generated at TA-21. Significant volumes of waste, both solid and liquid, were generated in an effort to cleanup and recycle the plutonium found in the effluent waste streams generated during the production processes. This included the dissolution of casting and reduction crucibles and miscellaneous solids including plutonium turnings from machining operations. Similarly, solids from incinerator reduction operations were dissolved in nitric and hydrofluorous acids to recover trace amounts of plutonium. Non-combustables as well as halogenated waste solutions and solutions containing organics were treated and extracted to recover plutonium. It was these recovery efforts which generated the bulk of the solid and liquid waste streams which were either stored or treated prior to discharge.

The dissolution of reduction and casting residues was started in 1946 (Christensen and Maraman, 1969). The process involved the addition of the slag, crucible, and packing sand into a 12 liter reaction vessel. Chemicals consisting of 0.8M $Al(NO_3)_3$ and 15.6M $HNO_3$ were added. The solids precipitated were then filtered and washed with 6M $HNO_3$. The washing solutions were combined with the filtrate and transfered to a purification system using either tri-n-butyl phosphate or a cation-exchange system. The extraction processes used during the 1940's varied widely as to the types and quantites of chemicals used. Experimental work from March to August 1944 showed that plutonium metal could be dissolved in the common mineral acids HCl, HI, HBr, and $HNO_3$-HF mixture. Of these, it was believed that HCl was the best choice for the dissolution of plutonium metal and it was used almost exclusively during 1945 and 1946 until research suggested that either HI or $HNO_3$-HF would be most suitable for plant procedure (Christensen and Maraman, 1969).

Attempts were made in 1946 to recycle metal turnings and scrap by direct hydrofluorination, but the plutonium metal yields were not good when bomb reduction by calcium metal was used.

Dissolution in HI was the method selected for large-scale processing starting in 1947. HI was selected because the process used for the production of plutonium metal was based on the precipitation of plutonium trioxalate. By using an excess of HI, it was believed that the dissolution of the material would be complete and the resulting solution would contain a plutonium specie in the trivalent state, thus eliminating the heretofore required valence adjustment step.

The main steps in the dissolution of plutonium were the addition of enough water to cover the metal in the dissolution vessels, the slow addition of 47% HI, and a 2 hour reflux. The disadvantages incurred by the use of this method included severe corrosion of equipment and frequent violent reactions associated with the ignition of the plutonium metal. In an attempt to circumvent these shortcomings, it was decided in 1951 to use the $HNO_3$-HF system. This process would be used until operations were shifted to TA-55.

The specific $HNO_3$-HF procedure used in 1969 for the dissolution of unalloyed plutonium required the addition of 1250 ml of 15.6M $HNO_3$ and 47% HF (added in milliliter increments to control the rate of dissolution). Once the requisite amount of HF had been added and the dissolution of the metal had stopped, the solution was heated and allowed to reflux for 2 hours at 105°C. The solution was then distilled until the volume reached 600 ml. Finally, the solution was allowed to cool and was filtered and sampled for analysis.

The residue from the filtration of the product were then leached three times with 12M $HNO_3$-0.05M HF and transfered to the fluoride fusion system for

further processing. The filtrate and wash solutions were then transfered to an anion-exchange system for purification. The distillate was sampled for plutonium analysis and transfered to the crucible processing system for removal of plutonium by one of the ion exchange systems (Christensen and Maraman, 1969).

C. Treatment and Disposal Technologies

Because of the scarcity of plutonium, much emphasis was placed on the recovery of this material from process waste streams. Thus, waste stream recycling became a common practice. It is safe to assume, however, that the primary reason recycling was implemented was to preserve the gram-quantities of plutonium which existed at the time and not as an effort to produce the least toxic waste stream. Similarly, the waste disposal systems common during the early 1940's-50's were not designed as true waste treatment and containment systems; they were trenches and adsorption beds excavated in the mesa top near the facility producing the waste stream. During the early 1940's, TA-21 had five operational waste disposal sites. These sites became known as Material Disposal Areas A, B, T, U, and V (Figure 1) These MDA's are discussed briefly below; detailed descriptions are provident in Sections 3 and 4.

Area A

Material Disposal Area A was used from 1945 to 1946. It is on the north side of TA-21 between DP-East and DP-West and covers about 53 800 $ft^2$ (Balo and Warren, 1986). The area contains 3 known pits (Gerety, Nyhan and Oliver, 1989) which were excavated in volcanic tuff for the burial of polonium contaminated wastes, which are now almost completely decayed, and possibly plutonium, uranium, and thorium contaminated wastes from TA-21 (Balo and Warren, 1986). The estimated volume of buried material is approximately 4 000 $yd^3$ and the pits were closed by July 1946. The area also contains two 50 000 $gallon^3$ tanks buried about 8 feet below grade. The tanks were built and installed in 1945 and the last known data detailing the content of the tanks is from August 1947 (Voelz, 1973). Waste solutions generated during the

plutonium precipitation processes were stored in these tanks with the hope that chemical recovery processes would improve so that the plutonium could be recovered. At the time the solutions were transferred into the tanks, radioassays indicate that a total of 344 grams of $^{239}Pu$ were placed in storage (Gibson, 1971). Later, in 1950 or 1951, corroborative samples taken from each tank for analysis indicated that the NaOH supernatant tank had about 180 grams $^{239}Pu$ in 50 000 gallons, and the $NH_4OH$ tank had about 160 grams $^{239}Pu$ in 35 000 gallons (Gibson, 1971).

(Author's Note: NaOH and $NH_4OH$ were used throughout the purification and recovery processes as precipitants. The hydroxide precipitation method can be used to remove certain impurities by the selection of either NaOH or $NH_4OH$ as the precipitating agent. With NaOH, amphoteric or acid elements such as aluminum or chromium could be redissolved by increasing the pH to >8. If the hydroxide cake was dissolved in $HNO_3$ and the hydroxides precipitated with excess $NH_4OH$, elements such a silver, copper, and zinc would form ammoniacal complexes and remain with the supernatant. If alkaline earths were present, the addition of $NH_4OH$ could be stopped at pH 5-6, thus preventing the formation of alkaline earth hydroxides and the alkaline earths could be removed with the supernatant by filtering before adding excess $NH_4OH$.)

An October 1973 assay of the contents of these tanks indicated that the radioactivity contained within was equivalent to about 230 grams of $^{239}Pu$, about one-third of which was $^{241}Am$ (Voelz, 1973). (Author's Note: According to the Chart of the Nuclides (Walker et al., 1983), $^{241}Am$ is a product resulting from the fission of plutionium mixed oxide fuels. It is produced at a rate of 0.251 Kg per metric ton at discharge for plutonium mixed oxide fuels) Further analysis indicated that only 0.7% of the radioactivity was in solution. On June 19, 1975 approximately 10 600 gallons of waste from the

west tank were transferred to TA-21-257 (waste treatment facility). Thus, when the liquid fraction was removed for treatment in 1983, several inches of a semi-solid precipiate containing the bulk of the activity was left in the tanks.

Material Disposal Area A was reactivated in April 1969 (Balo and Warren, 1986). An additional pit was excavated between the older pits to the east and the storage tanks to the west. Records indicate that the total volume was approximately 18 000 $yd^3$ (Desilets, 1972). The pit was used as a disposal site for low-level radioactively contaminated debris from the demolition work at TA-21 [e.g., TA-21-12 and TA-21-153 (filter buildings)] (Romero, 1969). This building debris is contaminated by Pu-239, Pu-238, U-235, and depleted uranium along with decay products and other radioactive isotopes which are found with these materials (Rogers, 1977). The disposal area remained active through September 1977 and was backfilled in May 1978.

Area A site stabilization was done in FY 1985. This included sealing and covering openings in the underground storage tanks to prevent any further water entry, removing surface contamination, adding cover material, recontouring, and reseeding the area. This site undergoes routine radiological monitoring under the Interim Waste Management Program (IWMP) of DOE's Office of Defense Waste and Transportation Management (DOE 1987).

## Area B

Area B was used from 1946 to 1948 for the disposal of wastes contaminated with radioactive materials and covers approximately 258 240 $ft^2$ (Balo and Warren, 1986). With available information, the exact number of pits cannot be determined. Research of archived information and employee interviews indicate that Area B was one large pit. The wastes

disposed of in Area B consisted primarily of solid wastes with various radioactive contaminants such as plutonium, polonium, uraninum, americium, curium, and actinium. It is estimated that no more than 100 gm of $^{239}Pu$ are contained in the pit (Balo and Warren, 1986). It is known that at least one truck contaminated with fission products from the Trinity Test is buried there. At the east end of Area B, several small slit trenches were dug for chemical disposal. These trenches were 3 to 4 ft deep, 2 ft wide, and less than 40 ft long. The chemicals disposed of there would include old bottles of organics, perchlorates, ethers, solvents, lecture bottles of mixtures, spent chemicals, old chemicals, and corrosive gases (Ahlquist, 1986). Chemical disposal in Area B was discontinued in 1948 when disposal was initiated in Area C.

The western two-thirds of Area B was covered with asphalt in 1966. The eastern one-third has been used since 1982 for in-situ experimental trench cap studies conducted under the auspicies of the Earth and Environmental Sciences Group (EES-15).

Area T

Material Disposal Area T consists of four adsorption beds for plutonium processing waste disposal, 62 asphalt-lined vertical shafts for low-level cement paste disposal, and a retrievable waste pit used until 1984. Two treatment plants, Bldg. 35 and Bldg. 257 have been used at the site.

The four inactive absorption beds were used from 1945 to 1952 for the subsurface disposal of liquid wastes from the recovery processes of plutonium. The absorption beds are trenches approximately 115 ft long, 20 ft wide, and 4 ft deep. The trenches were backfilled with coarse material, grading from 8 inch boulders at the bottom, through gravel, to fine sand at the surface.

Between 1945 and 1952, approximately 14 million gallons of untreated waste from plutonium (approximately 60 cpm/mL $^{239}Pu$) processing were discharged to the pits. This waste contained 140 mg/L sodium, 26 mg/L chloride, 7 mg/L calcium, 3 mg/L magnesium, 10 mg/L ammonia nitrogen, 75 mg/L nitrate nitrogen, and 160 mg/L fluoride as $F^-$ (average concentrations) (Christenson and Thomas, 1962). The discharge to the beds ranged from 3 000 to 12 000 gallons per day (GPD) during this period giving a surface loading rate (for beds 1 and 2) of 0.65 GPD/ft$^2$ to 2.61 GPD/ft$^2$ (beds 3 and 4 were used for overflow only and were not directly discharged to) (Christenson and Thomas, 1962). Further, between June 1951 and July 1952, some 10 500 gallons of citrate waste containing 50 000 mg/L di-ammonium citrate (Author's Note: Citrate is formed as a result of a complexation reaction during the plutionium purification process. In an effort to remove the citrate, which interferes with the purification process, $NH_2OH$-$HNO_3$ is added to reduce the plutonium to the trivalent state. Di-ammonium citrate is most likely formed during this reduction process), 800 mg/L magnesium, 160 mg/L calcium, 160 mg/L aluminum, 10 mg/L iron, 200 mg/L fluoride, 1680 mg/L nitrate nitrogen, and 7 000 cpm/mL $^{239}Pu$ were discharged to the beds (Christenson and Thomas, 1962).

Because the volume of the discharges often exceeded the holding capacity of the beds, after 1952 wastes were treated in Building TA-21-35 and at infrequent intervals, a few hundred gallons of treated wastes were discharged until 1967. Waste treatment operations then shifted to a new facility built at TA-21-257 in 1968. Wastes from these operations were mixed with cement and were pumped down asphalt-coated shafts augered between two absorption beds. This practice continued through 1974. Starting December 31, 1975, TRU wastes were mixed with cement and pumped into corrugated metal pipes which were stored in a pit dug between two absorption beds. Low level cement paste

continued to be pumped into shafts at the site through April, 1983. In August 1984, 70 corrugated metal pipes (contamination less than 100 nCi/g) were removed and by the close of 1984, some 158 pipes had been removed from Area T and transfered to Area G (Balo and Warren, 1986).

Many studies have been conducted to characterize the type of waste present in the absorption beds as well as to determine the extent of contaminant migration within the soil strata (See Section 3). Studies conducted in 1978 using 4 bore holes drilled at various locations within Area T indicated that $^{241}Am$ was present from the soil surface to 44 to 100 ft below the soil surface and $^{239}Pu$ was present from the soil surface 21.5 to 99.5 ft below the soil surface. The surface of Area T was stabilized in 1984 and is presently monitored for radioisotope transport.

Area U

Area U is on the northeast side of DP-East at TA-21 and consists of two absorption beds with a total surface area of 1 800 $ft^2$ (Walker et al., 1981). The beds are of the design found in Area T and were in operation from 1945 to 1968. During this period, it is estimated that the beds received a total waste volume of 18 000 $ft^3$ (135 000 gallons) (Walker et al., 1981). The detailed description of the contents of the waste stream is lacking, however, it is known that during 1953 the beds received approximately 2.5 Ci of $^{227}Ac$ and that over the life of the beds, the primary contaminant was $^{210}Po$ (Christensen, 1973). No records exist on the amount of $^{210}Po$ discharged; however, the short half-life of the material has by now resulted in decay to innocuous levels. Similarly, a 1972 assay for the presence of $^{227}Ac$ indicated that of the 2.5 Ci initially released in 1953, only 1.36 Ci were present owing to the relatively short half-life (21.7 yrs) of $^{227}Ac$. Area U was improved in

1985 with the removal of the piping from the absorption beds. Additionally, a trench (20 ft wide, 100 ft long, and 4 to 13 ft deep) was dug in the length of the beds and soil contaminated with $^{227}Ac$ was removed to Area G. The remediation activity was not completed, however, due to a lack of time and money and a plastic lining was placed in the trench to indicate the excavation boundary. The excavated area was then filled with uncontaminated tuff and covered with 6 inches of top soil. Presently, Area U is routinely surveyed for radioactive material transport (DOE, 1987).

Area V

Area V is southwest of TA-21 and east of Area B and covers approximately 43 040 $ft^2$ (Balo and Warren, 1986). The site consists of 3 interconnected pits 200 ft long, 25 ft wide, and 8 ft deep. The pits were excavated in 1945 for the disposal of liquid wastes from laundry operations and were in use through 1961 (Christenson, 1973). The pits were designed as filters and were filled to a depth of about 6 ft with large gravel at the bottom and subsequent layers of small gravel, soil , and tuff above. The capacity of each pit was about 60 000 gallons and they were designed to have a surface loading rate of no greater than 0.5 GPD/$ft^2$ (Abrahams, 1962; Christenson, 1973). The waste water was discharged into pit 1 where the water moved into and through the gravel and soil filter. Some water remained in pit 1, and some moved through overflow pipes into pits 2 and 3. The beds received wastes containing an estimated total of 3 Ci ($^{89}Sr$, $^{140}Ba$, and $^{140}La$), which have decayed over the years. In addition, small quantities of $^{90}Sr$ and $^{239}Pu$ were contained in the liquid wastes. In January 1984 the area was isolated with a chainlink fence and surface stabilization work was completed during FY 1985 (Balo and Warren, 1986).

D. Process Waste Streams

Archive searching has provided qualitative and quantitative data for determination of disposal practices used by early employees of the Laboratory to eliminate the wastes generated during normal plant operations. Many explanations exist which answer the question of "what chemical went where and in which disposal area?". However, the best approach to solving this problem seems to lie in trying to puzzle through the early scientist's thoughts on how to dispose of a process waste stream. Since the waste generated by a process is a "fingerprint" unique to the process itself, by knowing something about the initial process, it becomes less difficult to determine the type of contaminant most likely present in a disposal area.

In the mid-1950's, a study was performed to develop methodologies for the removal of radioactive materials from low-level wastes using the natural properties of the soils and clays found on the Laboratory site. The ultimate objective of the study was to develop a practical waste treatment process that would produce an effluent which met the drinking water standards of that time (Unknown, 1955). The scientists believed that a seepage pit, designed to handle the large volumes of low-level waste being generated, must have a minimum percolation rate of 2 GPD/ft$^2$ in order to be of practical size. Further, a 1948 study indicated that the percolation of plutonium-bearing wastes through local soils achieved a $10^4$ decontamination factor. Other studies indicated that the local soils achieved a 95% removal of radio-strontium (Unknown, 1955). Thus, it becomes readily apparent why the scientists chose to build absorption beds. They had found a treatment technique which was cost-effective and which relied upon the surface adsorption characteristics of the tuff, a medium which was available in great

quantites at a reasonable price and which tended to strongly bind the contaminant material thereby preventing significant migration.

In the early 1940's, the extraction processes used to purify the raw plutonium coming from Hanford were crude and inefficient at best. Although the scientists recycled the waste streams in order to remove the largest quantity of plutonium, a fraction still remained in solution. Thus, it was believed that at some point there might exist a process which would allow the scientists to remove this small fraction in solution. Therefore the solutions were stored in the "General's Tanks" in Area A. However, it is believed that by 1948 the extraction processes had improved significantly, as had the purity of the plutonium coming from Hanford, and it became unnecessary to store the liquid fraction of the processing wastes. It then became necessary to find a suitable disposal site since the "General's Tanks" had been closed in 1947. Whether or not the researchers felt that the removal efficiencies of the extractions processes were high enough to prevent environmental degredation is unclear. However, in 1948, it appears that a decision was made to discharge all processing wastes to Area T. Whether or not this waste was ever discharged to Area U is unknown. It is known that Area U contains plutonium, polonium, and actinium; however, the literature indicates that this waste was derived from the processing operations at DP East. Although Area T received waste as early as 1945, it is believed that the wastes disposed of were those generated as a result of efforts to recover/remove plutonium from process equipment, i.e., crucibles, casting skulls, contaminated paper, tools, and rubber gloves. Evidence seems to indicate that the waste placed in the tanks in Area A were those generated during the initial dissolution of the raw plutonium material received from Hanford. These wastes contained high concentrations of plutonium, uranium, and nitrate-nitrogen and research

indicates that the early researchers had difficulty separating plutonium from uranium. Thus, both elements were present in the tank solutions.

From the early 1940's until 1951, various dissolution processes were attempted using different types of acids. These acids included HCl, $H_2SO_4$, HBr, HI, $H_3PO_4$, HF, and $HNO_3$. Not until 1951 was it decided that the $HNO_3$-HF system provided the best results (Christenson and Maraman, 1969). This process was used until 1978 when plutonium processing was transfered to TA-55. Likewise, the extraction/precipitation process underwent several modifications over the years and the following chemicals were used (chemical/year used): sodium acetate (1944), oxalate (1944), ethyl ether (1944), ammonium nitrate, sodium nitrate, sodium bromotrioxide, fluoride, aluminum nitrate, ammonium hydroxide, sulfur dioxide, sodium hydroxide, thenoyl-tri-fluoroacetone (1947), and tri-n-butyl phosphate (TBP) in a kerosene carrier (1953). After 1953, plant systems using TBP as extractant were usually unable to give complete separation of plutonium and all other elements. One of the elements that tended to follow along with plutonium was zirconium. Other extractants, such as tri-n-octylamine, Primene JMT, Armeen 2-12, 9D-178, tri-lauryl amine, and Amberlite LA-1, were investigated. In order to achieve the required plutonium/zirconium separation, it was necessary to use a combination of Amberlite LA-1 and 10% n-decyl alcohol. This process remained in use until the ion extraction process had advanced to a state that would give the desired product purity under proper conditions. The ion exchange process was used to remove the following elements from the plutonium: cerium, aluminum, uranium, zirconium, hafnium, iron, thorium, copper, osmium, iodine, magnesium, cobalt, tantalum, americium, gallium, chromium, nickel, manganese, molybdenum, mercury, bismuth, ruthenium, rhodium, neptunium, platinum, palladium, and iridium (Christenson and Maraman, 1969).

The purpose of the preceeding description is to give the reader an idea of the tremendous numbers of chemicals which could have been placed in the disposal areas at TA-21. Although investigation will indicate that not all of these elements and chemicals are present today, it seems worthwhile to consider as many as possible when preparing a site characterization plan.

## REFERENCES


Abrahams, J. H., "Radioactive Waste Dispoal at Los Alamos, NM", July, 1962, EES-15 File TA21-MDAV 21-018a.

Ahlquist, A. J., Draft Document, Subject: Material Disposal Areas at TA-21, 1986, EES-15 File TA21-MDAA 21-014.

Balo, K. A. and J. L. Warren, "Waste Management Site Plan", LA-UR 86990, March 1986.

Christensen, E. L. and W. J. Maraman, "Plutonium Processing at the Los Alamos Scientific Laboratory", LA-3542, April 1969.

Christenson, C. W., 1973, "Nuclide Inventory Data", Los Alamos Scientific Laboratory memorandum H7-CWC-437 to H. Jordan, November 8, 1973.

Christenson, C. W., Office Memorandum, Subject: Nuclide Inventory Data, November 3, 1973, EES-15 File TA21-MDAV 21-018a.

Christenson, C. W. and R. G. Thomas, "Movement of Plutonium through Los Alamos Tuff" in Second Ground Dispoal of Radioactive Wastes Conference; Technical Services U. S. Department of Commerce report TID-7628 pp. 249-282 (1962).

Desilets, J. L., "Material Dispoal Area "A" DP West", Los Alamos Scientific Laboratory memorandum ENG-2, thru J. B. Weldon to C. A. Reynolds (November 9, 1972).

DOE, "Comprehensive Environmental Assessment and Response Program, Phase I: Installation Assessment Los Alamos National Laboratory, "Draft, October 1987.

Gerety, Nyhan, and Oliver, "History and Geophysical Description of Hazardous Waste Disposal Area A, Technical Area 21", October 1989, LA-11591-MS.

Gibson, W. B., "Generals Tanks - Memo from Dean D. Meyer, December 3, 1971," Los Alamos Scientific Laboratory memorandum CMB-11 to W. J. Maraman (December 6, 1971).

Rogers, M. A., "History and Environmental Setting of LASL Near-Surface Land Disposal Facilities for Radioactive Wastes (Areas A, B, C, D, E, F, G and T)", Los Alamos Scientific Laboratory report LA-6848-MS Vol. 1 (June 1977).

Romero, W. F., Office Memorandum, Subject: Radioactive Contamination Survey: Structures DP-12 and DP-153, TA-21, February 19, 1969, EES-15 File TA21-MDAA 21-014.

Unknown, "Removal of Plutonium, Strontium, and Mixed Fission Products from Industrial Wastes by Filtration Through Various Types of Soil", 1955, EES-15 File TA21-MDAU 21-017b.

Voelz, G. L., "Waste Storage Tanks", Los Alamos Scientific Laboratory memorandum, H, to E. E. Winefield, October 30, 1973, EES-15 File TA21-MDAA 21-014.

Walker, F. W., D. G., Miller, F. Feiner, "Chart of the Nuclides, 13th Ed., General Electric Company, San Jose, 1983.

Walker, L. J., W. R. Hansen, D. C. Nelson, G. Maestas, W. J. Wenzel, F. A. Guevara, J. L. Wamen, J. C. Rodgers, J. M. Graf, "Alternative Transuranic Waste Management Strategies at Los Alamos National Laboratory", LA-8982-MS, September 1981.