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HAZARDOUS WASTE
PROGRAM

ATKEARNEY

December 13, 1995

Ms. Barbara Hoditsehck
State of New Mexico Environment Department
Hazardous and Radioactive Material Bureau
P.O. Box 26110
2044 Galisteo
Santa Fe, New Mexico 87502

Reference: Work Assignment No. G969; State of New Mexico Environment Department, Santa Fe, New Mexico; WIPP Disposal Phase Part B Permit Application Review; White Paper-Sensitivity Check, Exposure Point Concentrations.

Dear Ms. Hoditschek:

Enclosed please find the white paper entitled "Sensitivity Check of the Calculations Used for Determining the Exposure Point Concentrations for Volatile Organic Air Emissions From the WIPP Repository". The purpose of this paper was to evaluate concentrations of VOCs (carbon tetrachloride and 1,1,1 trichloroethane) at the facility boundary and panel face using different VOC concentrations and gas generation rates than those used by the DOE in their Part B permit application risk assessment. These data were compared with OSHA and risk-based residential exposure values to determine whether the mixed waste disposed in WIPP would pose a threat to human health and the environment.

The calculations assumed varying gas generation rates and VOC concentrations, but used DOE's basic formulas, HEPA filter diffusion values, air dispersion value, etc. Data showed, essentially, that the DOE could comply with OSHA and residential scenario risk assessment requirements for carbon tetrachloride and 1,1,1,-trichloroethane assuming their formulas, etc. are correct. Under one assumption, the value was "close" to the compliance limit, but the actual length of exposure due to an open panel would not be the 35 or 70 year time frame used in the formulas. It must be emphasized that we did not evaluate all possible exposure scenarios, and NMED should provide guidance as to the specific additional scenarios that must be evaluated, once NMED has had the opportunity to examine the white paper fully. For example, we did not compare the carbon tetrachloride and 1,1,1-trichloroethane concentrations at the top of the exhaust shaft to an occupational risk assessment value (which would differ from the OSHA standard and a residential value). This calculation should be conducted, but it might be better to require the DOE to address this as an NOD comment. It is recommended that the information provided in this white paper be used to formulate additional NOD comments (if the next version of Chapter D does not address the concerns).

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This is to ensure that the permit application includes calculations for "worst case", yet realistic scenarios.

Please feel free to contact me or Dave Walker should you have any questions. Also, we are in the process of preparing an executive summary that will be appended to the document, so that those interested in a overview of white paper contents can achieve this quickly.

Sincerely,

Connie Walker

Connie Walker
Program Manager

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ROUGH WORKING DRAFT

SENSITIVITY CHECK OF THE CALCULATIONS USED FOR DETERMINING THE EXPOSURE POINT CONCENTRATIONS FOR VOLATILE ORGANIC AIR EMISSIONS FROM THE WIPP REPOSITORY

Prepared for:

The New Mexico Environment Department

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December 13, 1995

ROUGH WORKING DRAFT

SENSITIVITY CHECK OF THE CALCULATIONS USED FOR DETERMINING THE EXPOSURE POINT CONCENTRATIONS FOR VOLATILE ORGANIC AIR EMISSIONS FROM THE WIPP REPOSITORY.

I. INTRODUCTION

In order to comply with the miscellaneous unit environmental performance standards for air emissions [20 NMAC 4.1, Subpart V, § 264.601(c)], the Department of Energy (DOE) was required to submit information within the Waste Isolation Pilot Plan (WIPP) RCRA Part B Permit Application, Revision 5.0 (permit application) to demonstrate that the design and operation of the WIPP underground repository will prevent releases that may have adverse effects on human health and the environment due to migration of waste constituents in the air. The most significant potential source of adverse air emissions from the repository is expected to be vapor phase volatile organic constituents (VOCs) within the void and pore spaces of the waste containers to be shipped to the WIPP. Section D (Table D-3) and Appendix D9 of the permit application provided Tables with the predicted exposure concentrations of VOCs that the WIPP workers and the general public would receive during operation of the WIPP due to presence of the VOCs in the WIPP repository waste containers. The exposure concentration for WIPP workers were calculated assuming that a worker was standing at the exhaust point for the ventilation air flowing through a single open panel. The exposure concentration for the general public was calculated assuming that a hypothetical person was living at the edge of the facility boundary. The facility boundary was assumed to be the 4 mile square boundary defined in the Land Withdrawal Act of 1992.

II. DESCRIPTION OF THE DOE CALCULATIONS OF WIPP AIR EMISSIONS

Based on information presented in the permit application, it is assumed that the DOE used the following steps to calculate the exposure concentrations for each VOC:

A. The first step was to predict the concentration of each VOC in each waste container to be disposed in the WIPP. The predictions were based on VOC chemical analysis of the headspace gases present in 700 containers of the various Waste Matrix Code Groups (WMCGs) to be sent to WIPP from the Rocky Flats site and the Idaho National Laboratory. The actual results of the analyses were provided in Appendix C2 of the permit application. An average drum headspace concentration of each VOC was calculated for each WMCG. Since the average drum headspace concentration of VOCs varied widely between WMCG, and since it is anticipated that the WMCGs with the highest average drum headspace concentration of VOCs (solidified organics) will make up only a small percentage of the overall volume of waste in the WIPP, DOE multiplied the average drum headspace concentration for VOC in each WMCG by a weighting factor. The weighting factor was apparently based on the total percentage of a specific WMCG to be disposed in the WIPP [obtained from Table 3-5 of the WIPP Transuranic Waste Baseline Inventory Report, CAO-94-1005, Revision 1, February 1995 (1995 WIPP TRU BIR)]. The weighted averages for each of the WMCGs were added together to obtain the Overall Weighted Average Drum Headspace Concentrations of each VOC in each drum (or drum equivalent) to be disposed in the WIPP.

B. The second step apparently conducted by DOE was to develop equations that would be used to calculate an occupational exposure concentration that a worker would receive due to VOCs in the waste emissions at the panel exhaust point of a single open panel at the time of maximum potential exposure (e.g., when six of the disposal rooms within a panel were filled with waste containers and the last disposal room was in the process of being filled).

A public exposure concentration due to the presence of VOCs in the single open panel emissions was also calculated for a member of the public at the facility boundary. The assumption was made that a hypothetical member of the public was living (residential scenario) at the edge of the 4 mile square facility boundary defined Land Withdrawal Act of 1992.

The equations used to calculate the occupational exposure concentration due to waste emissions at the exhaust point for ventilation air flowing through a single open panel took into account the number of drums (or drum equivalents) in a waste panel, the Overall Weighted Average Drum Headspace Concentration for each VOC, the diffusion of the headspace gases through the HEPA grade filters fitted to each container, and the fresh air ventilation rate through the six filled disposal rooms and one working disposal room.

A similar equation was used to calculate the public exposure concentration at the facility boundary due to the single open panel emissions, except that the ventilation rate for the entire mine was factored in instead of the ventilation rate within a single waste disposal panel. In addition, the result of the equation was multiplied by an air dispersion factor to take into account dispersion of the VOCs that would occur between the exhaust shaft outlet and the facility boundary. Note that the assumptions, data, and computer modeling that were used to calculate the diffusion rate through the HEPA grade filter and the air dispersion factor were not provided in the permit application. Therefore, the appropriateness of these factors could not be verified.

DOE then compared the predicted occupational exposure concentrations for each VOC due to waste emissions at the exhaust of a single open panel to the Occupational Safety and Health Administration (OSHA) 8-hour Permissible Exposure Limit for each VOC and found that the predicted open panel occupational exposure concentration was at least 3 orders of magnitude below the OSHA standard. The predicted public exposure concentration for each VOC due to the single open panel emissions were compared to 35-year health-based risk limits for each VOC and were found to be at least 2 orders of magnitude below the health-based risk limits.

C. The third step apparently performed by DOE was to develop an equation to calculate public exposure concentrations resulting from VOCs present in the single closed panel emissions for a member of the public at the facility boundary. Note that an occupational exposure concentration was not determined for the single closed panel emissions since it was assumed that the maximum occupational would be from a single open panel. The equations used to calculate the public exposure concentrations due to the VOCs in the single closed panel emissions took into account the number of drums (or drum equivalents) in a waste panel, the Overall Weighted Average Drum Headspace Concentration for each VOC, the average gas generation rate per drum and the equivalent gas generation rate due to panel volume reduction from creep closure (both of which increase the air pressure within a panel and provide the force to drive the VOCs from the single closed panel), the fresh air ventilation rate for the entire mine, and an air dispersion factor to take into account dispersion of the VOCs that would occur between the exhaust shaft outlet and the facility boundary.

   DOE then compared the predicted public exposure concentrations for each VOC from the single closed panel emissions to 35-year health-based risk limits for each VOC. DOE found that the predicted exposure concentrations were at least 2 orders of magnitude below the health-based risk limits.

III. DESCRIPTION OF CONCERNS REGARDING THE DOE CALCULATIONS OF WIPP AIR EMISSIONS

During the review of the predicted air emission data provided in the permit application, several concerns were noted regarding the assumptions used for the input parameters to the equations that DOE used to calculate occupational and public exposures. These concerns include:

A. The first concern is related to the use of the Overall Weighted Average Drum Headspace Concentrations of each VOC to calculate the predicted occupational and public exposures. The use of the Overall Weighted Average Drum Headspace Concentrations to calculate the predicted exposure concentrations means that the predicted exposures are based on the assumption that each of the 10 waste disposal panels at the WIPP will be filled with the exact same mixture (by waste volume) of WMCGs. It is not realistic to assume that the mixture of WMCGs will be the same for each panel, since it is unlikely that DOE will commit to carefully controlling the amount and type of waste to be placed in each panel. As a result, it is necessary to assess whether changing the assumed waste loading within a panel would significantly change the predicted exposure concentrations. In other words, it is important to determine whether the loading of the maximum possible volume of those WMCGs with the highest average drum headspace concentration of VOCs into a single panel would result in predicted exposure concentrations that exceed occupational limits or public health-based limits.

B. The second concern is related to the assumed gas generation rates that DOE used to calculate the predicted public exposure to air emissions from the closed waste disposal panels. The DOE assumed that the average gas generation rate due to the degradation of waste and/or waste containers would be 0.1 moles per drum per year. However, DOE did not describe the source, or the justification for choosing, the 0.1 moles/drum/year rate within the permit application. From discussions with DOE and their contractors, it appears that the 0.1 moles/drum/year was obtained from the November 15, 1994 Position Paper on Gas Generation in the Waste Isolation Pilot Plant, L.H. Brush, Appendix D. The 0.1 moles/drum/year is apparently DOE's "best" estimate for gas generation for anoxic corrosion under humid conditions from Table 1 of Larry Brush's July 8, 1991 paper. Since all of the available estimates and predictions of WIPP gas generation rates are based on a wide variety of assumptions that have not, and may never be, verified with results of experiments, it is necessary to determine whether increasing the assumed gas generation rates for waste within a closed panel would significantly change the predicted exposure concentrations. In other words, it is important to determine whether increasing the assumed gas generation rate to the reasonable maximum predicted gas generation rate would result in predicted exposure concentrations that exceed occupational limits or public health-based risk limits.

C. The third concern is related to accuracy and the appropriateness of the values assigned for the diffusion rate through the HEPA grade filter and the air dispersion factor within the exposure concentration calculations. Establishing the appropriateness of the diffusion rate and air dispersion factors will be very important since the DOE assigned diffusion rate greatly decreases the occupational exposure concentration at the panel exhaust point, and the DOE assigned air dispersion factor greatly decreases the public exposure concentration at the unit boundary. The appropriateness the values assigned for these parameters could not be verified since of the assumptions, data, and computer modeling that were used to calculate the diffusion rate and the air dispersion factor were not provided in the permit application.

IV. DESCRIPTION OF SCENARIOS FOR THE SENSITIVITY CHECK

The purpose of the sensitivity check was to determine whether the predicted occupational exposure and public exposure concentrations due to VOC emissions from the WIPP would exceed occupational limits or public health-based risk limits under several "reasonable worst case" scenarios. The sensitivity check was accomplished by modifying input parameters (related to gas generation and headspace gas concentrations) to the DOE equations used to calculate the predicted exposure concentrations. The input parameters were modified in accordance with the scenarios described below.

Scenario 1 - The predicted occupational exposure concentration (at the exhaust outlet of a waste disposal panel) and public exposure concentrations (at the facility boundary) for carbon tetrachloride and 1,1,1-trichloroethane due to single open panel emissions were calculated assuming that the panel is full of the WMCGs with the highest average drum headspace concentrations. The original DOE assumptions were used for all of the remaining input parameters (diffusion through a HEPA grade filter, the panel and mine ventilation rates, and the air dispersion factor) to the DOE equations.

Scenario 2 - The predicted public exposure concentrations (at the facility boundary) for carbon tetrachloride and 1,1,1-trichloroethane due to single closed panel emissions were calculated.

- Scenario 2.A. assumed that the closed panel was full of the WMCGs with the highest average drum headspace concentrations and that the gas generation rate was the same as the DOE assumption (0.1 moles/drum/year).

- Scenarios 2.B. and 2.C. also assumed that the closed panel was full of the WMCGs with the highest average drum headspace concentrations, but assumed that the gas generation rate would be 2.1 moles/drum/year and 5.0 moles/drum/year, respectively.

The 2.1 moles/drum/year gas generation rate was chosen since it represents the maximum summation of gas generation due to anoxic corrosion, microbial activity, and radiolysis of brine under humid conditions from Table 1 of Larry Brush's July 8, 1991 paper. The 5.0 moles/drum/year value is approximately halfway between the maximum summation of gas generation rates under humid conditions and the maximum summation of gas generation rates under inundated conditions from Table 1 of Larry Brush's July 8, 1991 paper. The 5.0 rate was chosen since it is possible that at least some of the containers in a closed waste disposal panel may be under inundated conditions at some point in time after panel seal emplacement. The original DOE assumptions were used for all other input parameters to the DOE equations.

Scenario 3 - The predicted occupational exposure concentrations (at the exhaust outlet of a waste disposal panel) for carbon tetrachloride and 1,1,1-trichloroethane due to emissions from a partially closed, partially open panel were calculated. Scenario 3 assumed that two disposal rooms within a waste panel had collapsed and the drums were crushed, while the roofs within the 5 remaining disposal rooms of the same panel were intact. It was also assumed that the panel seal was not yet in place. Scenario 3 assumed that the entire waste panel was full of the WMCGs with the highest average drum headspace concentrations and that the gas generation rate was the would be 2.1 moles/drum/year and 5.0 moles/drum/year, which are the reasonable maximum predicted gas generation rates. Scenario 3 required the use of both the open panel and closed panel equations. The original DOE assumptions were used for all other input parameters to the DOE equations.

Note that a public exposure concentration at the facility boundary was not calculated for Scenario 3 since the length of time that air emissions resulting from this scenario would actually occur for only a very short period of time compared to the 35-year and 70-year exposure times used to establish residential scenario health-based risk limits.

V. RESULTS OF THE SENSITIVITY CHECK

A. To start the sensitivity check, the weighting factor used to calculate the Overall Weighted Average Drum Headspace Concentrations of each VOC in each drum was changed to reflect very conservative panel loading, using the WMCGs with the highest average drum headspace concentrations of VOCs to obtain a Maximum Weighted Average Drum Headspace Concentration. Since the permit application and the available references did not provide the average drum headspace concentration of each VOC in each WMCG, the average drum headspace concentrations of two VOCs (carbon tetrachloride and 1,1,1-trichloroethane) were calculated for each WMCG using the analytical data provided in Appendix C2 of the permit application. Carbon tetrachloride was chosen because the permit application indicated that the predicted exposure concentrations for carbon tetrachloride were the closest to the both occupational exposure and public exposure standards. 1,1,1-trichloroethane was chosen since the constituent appeared to be prevalent in many of the 700 drums analyzed.

1. The average drum headspace concentration of carbon tetrachloride and 1,1,1-trichloroethane in each drum was calculated for each WMCG using the analytical data provided in Appendix C2 of the permit application. The concentration assigned to samples where carbon tetrachloride and 1,1,1-trichloroethane was not detected was one-half of the reported detection limit. The results of the calculations are provided in Tables 1 and 3.

2. As a cross check to determine whether the average drum headspace concentrations of carbon tetrachloride and 1,1,1-trichloroethane for each WMCG calculated in this manner were similar to the concentration calculated by DOE, the average drum headspace concentrations (determined during the sensitivity check) were multiplied by the DOE weighting factor to obtain the weighted average concentration for each constituent for each WMCG. The weighted averages were then added together to derive the Overall Weighted Average Drum Headspace Concentration of carbon tetrachloride and 1,1,1-trichloroethane in each drum. The calculated carbon tetrachloride weighted concentration was 407.7 ppmv, which is essentially the same as the 408 ppmv calculated by DOE. The calculated 1,1,1-trichloroethane weighted concentration was 338.06 ppmv, which is almost the same as the 308 ppmv calculated by DOE. The result of the calculations are provided in Tables 2 and 4. Again, the purpose of this activity was to determine whether the average concentration of the two constituents in each drum in each WMCG was calculated in the same manner as done by DOE. Using the weighting factor comparison, it was apparent that the average drum headspace concentration calculated during the sensitivity check was similar to the value calculated by DOE.

3. The next step was to determine what a Maximum Weighted Average Drum Headspace Concentration of carbon tetrachloride and 1,1,1-trichloroethane per drum would be for one panel filled with the WMCGs with the highest average drum headspace concentrations of each of these constituents. This was done as follows:

<u>Carbon Tetrachloride</u>

The WMCGs with the highest average drum headspace concentrations of carbon tetrachloride were solidified organic waste (13,014.37 ppmv) and combustible waste (640.3 ppmv). Page B-10 of the permit application indicates that each disposal panel has a capacity of 17,354 cubic meters of contact handled (CH) waste. Since each 55-gallon drum can hold 0.208 cubic meters of waste, each disposal panel has a capacity of 83,432.6 drum equivalents. The WIPP TRU Waste Baseline Inventory Report, February 1995 (Table 3-5) indicates that the WIPP will receive a maximum anticipated volume of:

- 2100 cubic meters (10,096.1 drum equivalents) of solidified organic waste; and
- 62,000 cubic meters (298,077 drum equivalents) of combustible waste, of which only 73,336.5 drum equivalents would be needed to fill the remainder of one panel.

Therefore, the highest carbon tetrachloride concentration in a panel would be achieved by disposing 10,096 drum equivalents of solidified organic waste and 73,336.5 drum equivalents of combustible waste in that panel. Given this information, the Maximum Weighted Average Drum Headspace Concentration of carbon tetrachloride for each drum in a single disposal panel was calculated to be 2137.67 ppmv. The calculations and results are shown in Table 5.

1,1,1-Trichloroethane

The WMCGs with the highest average drum headspace concentrations of 1,1,1-trichloroethane were solidified organic waste (7687.77 ppmv) and heterogeneous waste (836.36 ppmv). A disposal panel has a capacity of 83,432.6 drum equivalents. The WIPP TRU Waste Baseline Inventory Report, February 1995 (Table 3-5) indicates that the WIPP will receive a maximum anticipated volume of:

- 2100 cubic meters (10,096.1 drum equivalents) of solidified organic waste; and
- 39,000 cubic meters (187,500 drum equivalents) of heterogeneous waste, of which only 73,336.5 drum equivalents would be needed to fill the remainder of one panel.

Therefore, the highest 1,1,1-trichloroethane concentration in a panel would be achieved by disposing of 10,096 drum equivalents of solidified organic waste and 77,337 drum equivalents of heterogeneous waste in that panel. Given this information, the Maximum Weighted Average Drum Headspace Concentration of 1,1,1-trichloroethane for each drum in a single disposal panel was calculated to be 1665.44 ppmv. The calculations and results are shown in Table 5.

B. Results: Scenario 1 - The maximum occupational exposure concentrations and the maximum public exposure concentrations due to single open panel emissions were calculated by inputing the Maximum Weighted Average Drum Headspace Concentration of carbon tetrachloride and 1,1,1-trichloroethane for each drum in a disposal panel into the DOE equations described in Section II.B. All of the other DOE input parameters remained the same. The equations, input parameters and results are shown on Table 6 and Table 7.

Maximum Occupational Exposure Concentrations

The predicted maximum occupational exposure concentration (Table 6) for carbon tetrachloride in the air at the exhaust outlet of a single open panel is 0.23 ppmv. The concentration of 0.23 ppmv of carbon tetrachloride is two orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

The predicted maximum occupational exposure concentration (Table 6) for 1,1,1-trichloroethane in the air at the exhaust outlet of a single open panel is 0.20 ppmv. The concentration of 0.20 ppmv of 1,1,1-trichloroethane is two orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

Maximum Public Exposure Concentrations

The predicted maximum public exposure concentration (Table 7) for carbon tetrachloride in the air at the facility boundary due to single open panel emissions is 1.77×10^{-2} ug/m^3. The concentration of 1.77×10^{-2} ug/m^3 of carbon tetrachloride is one order of magnitude below the 35 year health-based limit of 1.33×10^{-1} ug/m^3 and slightly below the 70 year health-based limit of 6.7×10^{-2}.

The predicted maximum public exposure concentration (Table 7) for 1,1,1-trichloroethane in the air at the facility boundary due to single open panel emissions is 1.29×10^{-2} ug/m^3. The concentration of 1.29×10^{-2} ug/m^3 of 1,1,1-trichloroethane is two orders of magnitude below the 35 year health-based limit of 1.25 ug/m^3 and one order of magnitude below the 70 year health-based limit of 6.25×10^{-1}.

Note that both the 35- and 70-year health-based limits were calculated based upon modified methodologies as presented in Chapter 5, Section 5.1.3, Methodology for Determining Health-Based Levels, of the May 31, 1995 WIPP No Migration Variance Petition (NMVP).

C. Results: Scenario 2 - The maximum public exposure concentrations due to the single closed panel emissions were calculated by inputing the Maximum Weighted Average Drum Headspace Concentration of carbon tetrachloride and 1,1,1-trichloroethane for each drum in a disposal panel into the DOE equations described above in Section II.C. The maximum public exposure concentrations were calculated using three different assumed gas generation rates (0.1, 2.1, and 5.0 moles/drum/year) to estimate the effect on the exposure concentrations. All of the other DOE input parameters remained the same. The equations, input parameters and results are shown on Table 8. Note that the maximum occupational exposure at the panel exhaust in the subsurface was not calculated since it was assumed that the maximum occupational exposure would occur under Scenario 1.

Carbon Tetrachloride

The predicted maximum public exposure concentration (Table 8) for carbon tetrachloride in the air at the facility boundary due to single closed panel emissions and a gas generation rate of 0.1 moles/drum/year is 2.32×10^{-4} ug/m^3. The concentration of 2.32×10^{-4} ug/m^3 of carbon tetrachloride is three order of magnitude below the 35 year health-based limit of 1.33×10^{-1} ug/m^3 and two orders of magnitude below the 70 year health-based limit of 6.7×10^{-2}.

The predicted maximum public exposure concentration (Table 8) for carbon tetrachloride in the air at the facility boundary due to single closed panel emissions and a gas generation rate of 2.1 moles/drum/year is 1.16×10^{-3} ug/m^3. The concentration of 1.16×10^{-3} ug/m^3 carbon tetrachloride is two order of magnitude below the 35 year health-based limit of 1.33×10^{-1} ug/m^3 and one order of magnitude below the 70 year health-based limit of 6.7×10^{-2}.

The predicted maximum public exposure concentration (Table 8) for carbon tetrachloride in the air at the facility boundary due to single closed panel emissions and a gas generation rate of 5.0 moles/drum/year is 2.51×10^{-3} ug/m^3. The concentration of 2.51×10^{-3} ug/m^3 of carbon tetrachloride is two orders of magnitude below the 35 year health-based limit of 1.33×10^{-1} ug/m^3 and one order of magnitude below the 70 year health-based limit of 6.7×10^{-2}.

1,1,1-Trichloroethane

The predicted maximum public exposure concentration (Table 8) for 1,1,1-trichloroethane in the air at the facility boundary due to single closed panel emissions and a gas generation rate of 0.1 moles/drum/year is 1.57×10^{-4} ug/m^3. The concentration of 1.57×10^{-4} ug/m^3 of 1,1,1-trichloroethane is four orders of magnitude below the 35 year health-based limit of 1.25 ug/m^3 and three orders of magnitude below the 70 year health-based limit of 6.2×10^{-1}.

The predicted maximum public exposure concentration (Table 8) for 1,1,1-trichloroethane in the air at the facility boundary due to single closed panel emissions and a gas generation rate of 2.1 moles/drum/year is 7.48×10^{-4} ug/m^3. The concentration of 7.48×10^{-4} ug/m^3 of 1,1,1-trichloroethane is four orders of magnitude below the 35 year health-based limit of 1.25 ug/m^3 and three orders of magnitude below the 70 year health-based limit of 6.2×10^{-1}.

The predicted maximum public exposure concentration (Table 8) for 1,1,1-trichloroethane in the air at the facility boundary due to single closed panel emissions and a gas generation rate of 5.0 moles/drum/year is 1.69×10^{-3} ug/m^3. The concentration of 1.69×10^{-3} ug/m^3 of 1,1,1-trichloroethane is three orders of magnitude below the 35 year health-based limit of 1.25 ug/m^3 and two orders of magnitude below the 70 year health-based limit of 6.2 x 10^{-1}.

D. Results: Scenario 3 - The maximum occupational exposure concentrations due to the emissions for a partially closed, partially open panel were calculated using a combination of the DOE equations described above in Sections II.B and II.C. The scenario required inputing the Maximum Weighted Average Drum Headspace Concentration of carbon tetrachloride and 1,1,1-trichloroethane for each drum in a disposal panel into the DOE equations. Three different gas generation rates (0.1, 2.1, and 5.0 moles/drum/year) were assumed for input into the closed panel equations. All of the other DOE input parameters remained the same. The equations, input parameters and results are shown on Table 9.

Note that a public exposure concentration at the facility boundary was not calculated for Scenario 3 since the length of time that air emissions resulting from this scenario would actually occur for only a very short period of time compared to the 35-year and 70-year exposure times used to establish residential scenario health-based risk limits.

Carbon Tetrachloride

The predicted maximum occupational exposure concentration (Table 9) for carbon tetrachloride in the air at the exhaust outlet of a partially closed, partially open panel with an assumed gas generation rate of 0.1 moles/drum/year is 0.84 ppmv. The concentration of 0.84 ppmv of carbon tetrachloride is between one and two orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

The predicted maximum occupational exposure concentration (Table 9) for carbon tetrachloride in the air at the exhaust outlet of a partially closed, partially open panel with an assumed gas generation rate of 2.1 moles/drum/year is 0.87 ppmv. The concentration of 0.87 ppmv of carbon tetrachloride is between one and two orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

The predicted maximum occupational exposure concentration (Table 9) for carbon tetrachloride in the air at the exhaust outlet of a partially closed, partially open panel with an assumed gas generation rate of 5.0 moles/drum/year is 0.91 ppmv. The concentration of 0.91 ppmv of carbon tetrachloride is between one and two orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

1,1,1-Trichloroethane

The predicted maximum occupational exposure concentration (Table 9) for 1,1,1-trichloroethane in the air at the exhaust outlet of a partially closed, partially open panel with an assumed gas generation rate of 0.1 moles/drum/year is 0.61 ppmv. The concentration of 0.61 ppmv of 1,1,1-trichloroethane is between one and two orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

The predicted maximum occupational exposure concentration (Table 9) for 1,1,1-trichloroethane in the air at the exhaust outlet of a partially closed, partially open panel with an assumed gas generation rate of 2.1 moles/drum/year is 0.63 ppmv. The concentration of 0.63 ppmv of 1,1,1-trichloroethane is between one and two orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

The predicted maximum occupational exposure concentration (Table 9) for 1,1,1-trichloroethane in the air at the exhaust outlet of a partially closed, partially open panel with an assumed gas generation rate of 5.0 moles/drum/year is 0.66 ppmv. The concentration of 0.66 ppmv of 1,1,1-trichloroethane is between one and two orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

V. OTHER CONSIDERATIONS

Other potential exposure scenarios for air emissions from the WIPP that were not addressed in permit application, or this sensitivity analysis, may warrant consideration. For example, the potential exposure concentrations to WIPP personnel who worked in the above ground WIPP support facilities, but who were not engaged in waste management activities, may warrant evaluation. Also, the exposure concentrations to a hypothetical illegal trespasser living at the WIPP facility may need to be investigated.

The maximum exposure concentration of VOCs to the non-waste handling WIPP worker due to air emissions from the WIPP would be expected to be less than the maximum occupational exposure concentration at the panel exhaust outlet, but greater than the maximum public exposure concentration at the facility boundary. A relatively simple way of estimating the exposure concentration to the non-waste handling WIPP worker would be to remove the air dispersion factor from the maximum public exposure concentration at the facility boundary from underground emissions from a single open waste panel calculated in Table 7. The single open panel was chosen since it resulted in the highest public exposure concentration at the facility boundary. The resulting concentration would be an estimate of the VOC concentration in the air exiting the top of the exhaust shaft. This concentration could then be compared to OSHA 8-hour permissible exposure limit.

Table 7 indicates that the predicted maximum public exposure concentration for carbon tetrachloride in the air at the facility boundary due to single open panel emissions is 1.77 x 10^{-2} ug/m^3. If this concentration is divided by the air dispersion factor of 0.000107, the resulting concentration is 165.42 ug/m^3. The equivalent concentration in ppmv is 0.026 ppmv of carbon tetrachloride which is four orders of magnitude below the OSHA 8-hour permissible exposure limit of 10 ppmv.

The maximum exposure concentration of VOCs to the hypothetical trespasser living at the WIPP site could be calculated by removing the air dispersion factor from the maximum public exposure concentration at the facility boundary from underground emissions from a single closed panel calculated in Table 7. The single closed panel was chosen since a residential scenario would be assumed for a person living at the WIPP and the residential scenario health-based limits are based on exposures of 35-years and 70-years. The panel filled with the WMCGs with the maximum weighted average drum headspace concentration would be closed relatively quickly in comparison to a 35-year or 70-year residential scenario.

Table 8 indicates that the predicted maximum public exposure concentration for carbon tetrachloride in the air at the facility boundary due to single closed panel emissions is 2.51 x 10^{-3} ug/m^3. If this concentration is divided by the air dispersion factor of 0.000107, the resulting concentration is 23.46 ug/m^3, which is two orders of magnitude above the 35 year health-based limit of 1.33 x 10^{-1} ug/m^3 and three orders of magnitude above the 70 year health-based limit of 6.7 x 10^{-2}.

TABLE 1 – Sample Data by Waste Matrix Code Group for Carbon Tertrachloride

Data from Appendix C2 – Data Accumulated From Headspace Analysis
: WIPP Waste Characterization Program, Gas Chromatography/ Mass Spectrometry Results
: Pages C2–29 through C2–54
: All data reported in ppmv, all nondetects reported as 0.04 ppmv, indicated by shading
: Data organized according Waste Matrix Code Groups (No data reported for soil and unknowns)

Combustible Waste (total nondetects = 23)					
0.35	0.05	1	0.03	0.04	0.04
28	13	0.55	3800	0.04	0.04
0.2	0.18	140	20	0.04	0.04
290	0.7	3.8	3400	0.04	0.04
290	150	22	0.04	0.04	0.04
0.13	3700	0.48	0.04	0.04	
15	0.43	1	0.04	0.04	
0.03	1300	0.1	0.04	0.04	
0.06	0.75	0.07	0.04	0.04	
25000	42	130	0.04	0.04	
1.2	65	1.1	0.04	0.04	
Total Average Concentration, ppmv :			640.3022		

Filter Waste (total nondetects = 20)					
0.02	0.056	0.04	0.04	0.04	0.04
5.6	2.3	0.04	0.04	0.04	0.04
36	0.04	0.04	0.04	0.04	
0.05	0.04	0.04	0.04	0.04	
0.13	0.04	0.04	0.04	0.04	
Total Average Concentration, ppmv :			1.665037		

Graphite Waste (total nondetects = 0)					
0.1	0.04	0.04	0.06	0.1	0.03
0.03	0.07	0.03	0.15	0.07	0.01
0.02	0.05	0.12	0.06	0.19	0.02
0.06	0.07	0.03	0.02	0.1	0.01
0.05	0.05	0.08	0.03	0.03	
0.03	0.04	0.07	0.06	0.04	
0.04	0.04	0.03	0.04	0.09	
Total Average Concentration, ppmv :			0.05641		

Heterogeneous Waste (total nondetects = 102)					
4.06	1.5	0.61	0.04	0.04	0.04
0.26	0.13	0.35	0.04	0.04	0.04
0.27	2.9	0.48	0.04	0.04	0.04
1.77	14	0.48	0.04	0.04	0.04
0.78	4	0.26	0.04	0.04	0.04
133.99	0.52	0.38	0.04	0.04	0.04
21.9	0.44	10.07	0.04	0.04	0.04
1170.25	0.36	4.48	0.04	0.04	0.04
1265.63	0.09	0.25	0.04	0.04	0.04
15.72	1.1	0.33	0.04	0.04	0.04
214.07	0.24	3.54	0.04	0.04	0.04
1.36	0.14	0.76	0.04	0.04	0.04
0.27	0.31	0.49	0.04	0.04	0.04
0.22	0.8	0.33	0.04	0.04	0.04
0.55	0.04	0.25	0.04	0.04	0.04
19.3	36	0.33	0.04	0.04	0.04
127.73	106	1946.06	0.6	0.04	0.04
6.2	24	2458.88	1.87	0.04	0.04
50	70	0.35	63.67	0.04	0.04
35	25	0.4	0.24	0.04	0.04
83	37	0.22	0.31	0.04	0.04
92	22	0.13	22.39	0.04	0.04
125	30	43.36	37.08	0.04	0.04
50	75	164.99	0.37	0.04	0.04
120	110	0.61	0.33	0.04	0.04
65	65	0.13	0.4	0.04	0.04
90	105	0.6	0.21	0.04	0.04
69.15	63	0.24	0.23	0.04	0.04
0.45	6912.5	0.28	0.31	0.04	0.04
0.22	887.74	0.34	0.69	0.04	0.04
0.21	0.26	0.74	0.97	0.04	0.04
0.31	8.78	0.51	0.21	0.04	0.04
0.56	0.55	0.81	0.65	0.04	0.04
0.23	36.34	7.12	0.81	0.04	0.04
1.16	334.76	0.65	0.79	0.04	0.04
0.13	0.33	0.58	0.3	0.04	0.04
5.78	11.69	0.46	0.04	0.04	0.04
0.49	0.14	5153.24	0.04	0.04	0.04
15.11	0.13	0.64	0.04	0.04	0.04
0.3	0.23	1.75	0.04	0.04	0.04
25	0.33	0.31	0.04	0.04	
Total Average Concentration, ppmv : 92.83706					

Solidified Inorganic Waste (total nondetects = 64)							
0.21	0.4	0.39	0.14	0.04	0.04	0.04	0.04
0.69	0.47	402.58	0.97	0.04	0.04	0.04	0.04
0.3	0.28	0.19	10	0.04	0.04	0.04	0.04
2.3	0.31	0.6	0.84	0.04	0.04	0.04	0.04
1.09	0.5	0.23	4.26	0.04	0.04	0.04	0.04
0.65	0.23	0.18	0.15	0.04	0.04	0.04	0.04
0.22	0.78	0.27	1.04	0.04	0.04	0.04	0.04
0.3	1.4	0.17	11.65	0.04	0.04	0.04	0.04
0.48	0.54	0.1	0.86	0.04	0.04	0.04	
0.54	0.93	0.41	0.26	0.04	0.04	0.04	
0.27	675.83	0.07	0.12	0.04	0.04	0.04	
0.68	0.36	494.2	0.25	0.04	0.04	0.04	
0.23	0.13	0.07	0.04	0.04	0.04	0.04	
0.1	0.34	0.03	0.04	0.04	0.04	0.04	
0.03	0.34	0.07	0.04	0.04	0.04	0.04	
0.18	0.23	0.36	0.04	0.04	0.04	0.04	
1.8	0.18	0.14	0.04	0.04	0.04	0.04	
Total Average Concentration, ppmv :			12.80693				

Solidified Organic Waste (total nondetects = 10)							
0.014	6364.65	15000	300	27354	66727.2	5328.18	0.04
1.52	6225.74	6700	640	12796.8	88612.87	0.04	0.04
12.29	4240.32	52000	30767.52	2836.44	67524	0.04	
0.23	15676.74	6000	16369.8	1.29	88979	0.04	
0.21	6213.5	2.3	18198.16	1.32	1583.94	0.04	
0.24	62380.69	0.19	19219.27	0.25	6208.6	0.04	
0.1	8200	4.68	12288.62	0.89	12990.69	0.04	
2.42	5600	10000	34118.1	2.43	43418.14	0.04	
0.86	2100	3200	4459.13	61914.55	13365.81	0.04	
Total Average Concentration, ppmv :			13014.37				

Uncategorized Metal Waste (total nondetects = 33)							
37.08	0.09	0.12	0.21	0.04	0.04	0.04	0.04
58.86	0.05	0.07	0.51	0.04	0.04	0.04	0.04
0.13	0.14	0.1	0.07	0.04	0.04	0.04	0.04
0.2	0.03	0.16	2.45	0.04	0.04	0.04	0.04
62.96	0.09	0.79	0.45	0.04	0.04	0.04	
0.74	0.13	0.12	25.18	0.04	0.04	0.04	
600	5.5	0.1	1	0.04	0.04	0.04	
0.05	0.17	0.56	0.04	0.04	0.04	0.04	
0.11	0.06	29	0.04	0.04	0.04	0.04	
Total Average Concentration, ppmv :			12.36716				

Inorganic Non–Metal Waste (total nondetects = 16)					
1.8	66	0.65	0.32	0.04	0.04
0.96	0.66	0.19	0.22	0.04	0.04
0.35	0.26	0.19	0.28	0.04	0.04
0.28	0.18	0.22	0.35	0.04	0.04
0.25	0.26	0.09	0.23	0.04	0.04
0.26	0.22	0.24	83	0.04	
0.28	63	1.2	0.31	0.04	
0.47	0.39	0.25	0.44	0.04	
0.32	0.32	0.36	0.25	0.04	
2.3	0.21	0.19	0.1	0.04	
0.44	0.19	0.38	20.06	0.04	
Total Average Concentration, ppmv :			4.301379		

Lead/Cadmium Metal Waste (total nondetects = 8)					
413.64	3.87	0.04	0.04	0.04	0.04
2006.37	1.36	0.04	0.04	0.04	0.04
Total Average Concentration, ppmv :			202.13		

Salt Waste (total nondetects = 0)				
50	0.25	0.33	0.2	0.28
Total Average Concentration, ppmv :			10.212	

TABLE 2 – Carbon Tetrachloride Total Weighted Average

Total average concentrations per WMCG calculated from data presented in Appendix C2
Weighting factors (WF) from Table HSC–1 (Weighting Factors used to Calculate Average VOC Concentrations in Drum Headspace), Appendix HSC, NMVP

Weighted Average for WMCG = Average Concentration x Weight Factor
Total Weighted Average for Carbon tetrachloride = Sum Weighted Averages

WMCG	Avg. conc.	Weight Factor	Weighted Avg.
combustible	640.3	0.3528	225.90
Filter	1.67	0.0148	0.02
Graphite	0.06	0.0043	0.00
Heterogeneous	92.84	0.2219	20.60
Inorganic non–metal	4.3	0.0102	0.04
lead/cadmium metal	202.13	0.0018	0.36
salt	10.21	0.0009	0.01
solidified inorganic	12.81	0.1935	2.48
soilified organic	13014.37	0.012	156.17
uncategorized	12.37	0.1707	2.11
		Total Weighted Average =	407.70

TABLE 3 – Sample Data by Waste Matrix Code Group for 1,1,1–Trichloroethane

Data from Appendix C2 – Data Accumulated from Headspace Analysis

:WIPP Waste Characterization Program, Gas Chromotography/Mass Spectrometry Results

: Pages C2–29 through C2–54

: All data reported in ppmv

: All nondetects are indicated by shading

: Data organized by Waste Matrix Code Groups (No data reported for soil and unkowns)

Solid Inorganics (total nondetects = 16)							
0.32	0.15	6.7	3.2	210	51	33	49.01
0.33	0.59	66	0.87	1.8	38	16	165.71
0.46	0.3	220	6.4	98	50	14	0.93
0.25	0.63	40	38	110	92	18	0.62
34	44	0.16	40	190	39	27	28.65
0.19	56	22	680	92	150	63	118.35
0.17	45	6	13	29	30	23	72.31
0.23	40	4.3	4.7	120	63	81	21.61
490	38	43	78	69	130	35	91.7
290	14	260	180	51	51	140	0.83
170	18	19	100	21	75	0.32	199.52
0.3	0.12	0.9	1.4	0.1	0.43	429.17	6
0.98	0.14	1.26	0.28	1.8	0.56	0.46	0.1
0.12	0.36	1.11	0.13	1.83	0.68	0.32	0.1
41.04	7.62	31.39	48.1	0.18	2.44	4.25	0.1
0.7	0.1	0.1	0.4	0.2	0.1	0.1	0.1
0.1	0.1	3	0.1				
Total Average Concentration, ppmv 50.17561							

Combustible Waste (total nondetects = 1)							
0.12	0.09	220	140	19	12	14	84
0.78	290	390	140	0.55	65	12	100
0.18	0.06	1.1	110	820	88	70	53
12	0.13	300	120	74	29	84	2.5
4.8	0.19	55	53	32	48	2.6	
0.17	0.18	24	160	76	97	0.13	
8.2	0.11	59	250	48	38	71	
0.13	290	450	0.45	48	200	37	
Total Average Concentration, ppmv 88.40783							

Heterogeneous Waste (total nondetects = 94)								
0.17	0.31	4.86	2954.06	97.42	2711.75	1.6	1	1.2
45	0.32	403.75	0.47	33.16	0.21	0.5	0.51	0.2
0.2	0.68	4144.38	8372.6	0.2	0.28	0.27	0.2	0.3
200	0.32	14569.5	2679.91	0.1	0.2	6	0.2	0.4
92	3.96	6432.5	3750.4	0.2	0.45	1.6	0.7	0.13
75	108.25	348.67	15.2	0.25	0.35	111	0.1	0.1
160	0.76	36.09	4816.73	12.25	0.4	0.67	0.6	0.3
5.8	0.51	1.23	4070.64	0.46	5.02	0.2	0.1	6.67
85	0.52	481.6	0.36	3.12	17	0.1	0.3	0.3
92	0.23	45.18	20.43	0.51	0.45	0.1	0.2	0.3
200	0.49	0.56	1.01	0.3	0.2	0.2	0.2	0.3
85	30.09	14009.04	8313.3	0.13	0.12	0.27	220	0.2
310	3.32	0.31	0.53	4620.72	0.13	18.59	0.2	0.2
44	0.2	3.04	0.95	10516.8	0.33	0.2	0.3	0.27
120	2.43	2.3	4.64	0.17	0.27	0.1	0.3	0.6
70	45.12	7283.87	35533.4	1.89	0.5	2.8	0.3	0.2
50	1.52	0.52	0.2	0.17	0.2	2	0.5	100
23	681.08	2.49	0.52	0.14	0.1	1.5	10	0.1
56	664.72	0.2	0.48	47.56	0.27	0.5	15	0.13
91	394.11	11.24	2682.63	53.3	0.1	0.1	0.6	0.27
3	4170.22	29.48	0.14	3.61	13.33	18	0.27	0.2
24	34.29	0.37	0.21	0.82	0.4	7	113.33	1
250	1.13	0.5	1277.85	0.15	0.2	0.1	0.2	0.2
4597.49	0.19	10740.42	0.23	0.49	28	0.2	1.5	2
349.15	23.08	2205.72	364.82	0.73	0.47	0.5	0.1	0.2
2.01	10386.96	4021.87	1264.72	7343.03	0.27	0.54	0.3	0.2
62.32	9184.51	0.67	1343.49	3648.5	0.3	0.3	1.2	0.4
							0.2	0.1
Total Average Concentration, ppmv:			836.363					

Filter Waste (total nondetects = 12)						
0.03	23	13	0.31	0.1	0.5	0.1
21	100	0.34	1.99	0.1	0.4	0.4
88	44	9.99	0.76	0.1	0.5	0.5
42	0.49	1.37	0.1	0.4	0.4	
Total Average Concentration, ppmv:			12.95852			

Lead Waste (total nondetects = 7)					
5612.31	456.31	2.96	0.1	0.1	0.1
1594.38	0.16	0.2	0.1	0.27	0.3
Total Average Concentration, ppmv:			638.9408		

Salt Waste (total nondetects = 0)				
23	15	5.6	5	7.5
Total Average Concentration, ppmv	11.22			

Solidified Organic Waste (total nondetects = 4)							
1500	360	8430.3	13431.42	1.91	16.52	2.51	1020.17
530	280	916.24	13804.5	85795.53	0.99	1.42	4123
180	140	18543.75	55410.59	2.59	6.29	1.03	3535.36
4100	24947.1	4071.68	6.31	3.66	1.79	1.75	1068.57
1800	12909.74	731.16	21.3	24298	1.52	36.24	0.4
33000	904.15	2762.7	44413.75	36373	1.53	36.75	130
620	12516.43	2796.84	32496	0.93	3.18	257.42	48
18000	3392.86	8439.34	1.69	8.18	1.55	13758.8	21
Total Average Concentration, ppmv	7687.773						

Graphite Waste (total nondetects = 1)							
9.2	0.07	0.17	0.12	0.11	11	3.2	3.6
0.66	0.06	0.09	0.09	0.18	16	0.09	43
0.12	0.08	0.1	0.11	0.12	0.07	0.04	0.08
0.08	0.13	0.1	0.13	0.05	0.07	12	0.02
0.09	0.08	0.06	0.05	0.08	2.1	0.35	
Total Average Concentration, ppmv	2.660256						

Uncategorized Metal Waste (total nondetects = 12)							
0.14	12	180	130	60	1686.56	0.4	0.1
0.43	10	15	12	44	912.67	1	0.1
13	11	19	1.2	40	130.61	2	0.1
0.05	22	0.84	170	2.8	1.97	1.6	
160	0.66	480	1.2	0.27	544.22	0.3	
20	56	94	42	1.08	20.4	0.27	
580	0.33	8.1	14	175.17	305	0.2	
2.2	48	130	56	2.27	30.42	0.1	
74	58	230	30	117.31	0.56	1	
Total Average Concentration, ppmv	102.4792						

Inorganic Metal Waste (total nondetects = 2)							
0.27	36	12	11	3.6	18	34	0.4
0.62	11	3.6	200	26	66	50	
0.72	37	83	0.25	2.6	24	130	
0.27	0.23	22	12	1	29	180	
0.29	140	14	0.25	33	75	5.4	
0.28	250	39	0.1	8.6	58	16	
0.26	7	2.9	1.3	37	44	0.36	
150	4	8.4	13	16	80	0.1	
Total Average Concentration, ppmv	35.06667						

TABLE 4 – Total Average Concentrations per WMCG for 1,1,1-Trichloroethane

Total average concentrations per WMCG calculated from data presented in Appendix C2
Weighting factors (WF) from Table HSC-1 (Weighting Factors used to Calculate Average VOC Concentrations in Drum Headspace), Appendix HSC, NMVP

Weighted Average for WMCG = Average Concentration x Weight Factor
Total Weighted Average for Carbon tetrachloride = Sum Weighted Averages

WMCG	Avg. conc.	Weight Factor	Weighted Avg.
combustible	88.71	0.3528	31.30
Filter	12.96	0.0148	0.19
Graphite	2.66	0.0043	0.01
Heterogeneous	836.36	0.2219	185.59
Inorganic non-metal	35.07	0.0102	0.36
lead/cadmium metal	638.94	0.0018	1.15
salt	11.22	0.0009	0.01
solidified inorganic	50.18	0.1935	9.71
soilified organic	7687.77	0.012	92.25
uncategorized	102.48	0.1707	17.49
Total Weighted Average =			338.06

TABLE 5 – Maximum Weighted Average Drum Headspace Concentration

Assumptions:

83432.6 = X = Number drum equivalents per panel, calculated based upon volume

0.208 = Volume of one drum equivalent, m^3

47000 = V = Panel ventilation rate (ft^3/min), from Table D9-1, Appendix D9

Maximum panel volumes (drum equivalents) per WMCG from 1995 WIPP TRU BIR:

Carbon Tetrachloride:

10096.1 = Solidified Organic (2100m^3)

73336.5 = Combustible (62000 m^3)

1,1,1-Trichloroethane:

10096.1 = Solidified Organic (2100 m^3)

73336.5 = Heterogeneous (39000 m^3)

Formula:

$$\text{Max Weighted Avg. Drum Headspace Conc.} = \frac{\text{(total concentration in a panel panel)}}{\text{(maximum drum equivalents per panel)}}$$

Carbon Tetrachloride:			
WMCG	Avg Conc, WMCG (ppmv)[1]	Max Drum Equiv. per panel	Total Conc. in a panel
Solidified Organics	13014.37	10096.10	131394380.96
Combustible	640.30	73336.50	46957360.95
		83432.60	178351741.91
Max Weighted Avg Drum Headspace Conc (ppmv)		[1] Calculated using data from Appendix C2 and the 1995 WIPP TRU BIR, See Table 1	
2137.67			

1,1,1-Trichloroethane:			
WMCG	Avg Conc, WMCG (ppmv)[1]	Max Drum Equiv. per panel	Total Conc. in a panel
Solidified Organics	7687.77	10096.10	77616494.70
Heterogeneous	836.36	73336.50	61335715.14
		83432.60	138952209.84
Max Weighted Avg Drum Headspace Conc (ppmv)		[1] Calculated using data from Appendix C2 and the 1995 WIPP TRU BIR, See Table 3	
1665.44			

TABLE 6 – Maximum Occupational Exposure From Underground Waste Emissions

Assumptions:

83432.6 = X = number of drum equivalents per panel, calculated based upon volume

47000 = V = panel ventilation rate (ft^3/min), from Table D9-1, Appendix D9

153.84 = MW_{CT} = molecular weight, g/mol, carbon tetrachloride, Table D9-1, Appendix D9

133.42 = MW_{TCA} = molecular weight, g/mol, 1,1,1-Trichloroethane, calculated

Formulae:

$$\text{Molfraction} = \frac{\text{(Maximum Weighted Average Drum Headpsace Concentration)}}{\text{(mol fraction / } 10^6 \text{ ppmv)}}$$

Average Drum Emission Rate (ADE) = (mol fraction)x(Carbon Composite Filter Diffusion Rate)

$$\text{Single open panel exhaust conc. from waste emissions} = \frac{[(X) \times (ADE) \times (MW) \times (10^6 \text{ug/g})]}{[(V) \times (0.0283 \text{ m}^3/\text{ft}^3) \times (\text{min}/60\text{s})]}$$

$$\text{Conversion to ppmv} = \frac{[(\text{ug/m}^3) \times (0.024)]}{(MW)}$$

Compound	Carbon Composite Filter Diffusion Rate[1,2] (mol/s/molfrac)	Max Weighted Avg Drum Headspace Concentration[3] (ppmv)	Mol Fraction (molfrac)	Average Drum Emission Rate (ADE) (mol/s/drum)	Single Open Panel Exhaust Concentration from Waste Emissions (ug/m³)	Single Open Panel Exhaust Concentration from Waste Emissions (ppmv)	29 CFR 1910.1000 OSHA 8-hr Permissible[1,4] Exposure Limit (ppmv)
Carbon Tetrachloride	1.21E-06	2137.67	2.14E-03	2.59E-09	1497.61	0.23	10.00
1,1,1-Trichloroethane	1.30E-06	1.67E+03	1.67E-03	2.17E-09	1087.17	0.20	10.00

NOTE:

[1] From Table D9-1, Appendix D9, for Carbon Tetrachloride

[2] Estimated for 1,1,1-Trichloroethane

[3] Calculated using data from Appendix C2 and the 1995 WIPP TRU BIR, See Table 5

[4] From the NIOSH Pocket Guide to Chemical Hazards, for 1,1,1-Trichloroethane

TA..E 7 – Maximum Public Exposure Concentration at the LWB fron ..derground Waste Emissions From a Single Open Waste Panel

Assumptions:

83432.6 = X = Number of drums per panel, calculated based upon volume of panel and drums
0.000107 = ADF_{CT} = Air Dispersion Factor, from Table D9–3, Appendix D9, Carbon tetrachloride
0.000107 = ADF_{TCA} = Air Dispersion Factor, from Table D9–3, Appendix D9, 1,1,1–Trichloroethane
425000 = V = Total mine ventilation rate, ft^3/min, from Table D9–3, Appendix D9

Formulae:

SOPE = single open panel emissions $\frac{(X) \times (ADF) \times (ADE) \times (MW) \times (10^6 ug/g)}{(V) \times (0.0283 m^3/ft^3) \times (min/60s)}$

Molfraction = $\frac{\text{(Max Weighted Avg Drum Headspace Conc)}}{(\text{molfraction}/10^6 \text{ ppmv})}$

ADE = average drum emission rate, mol/s
= Carbon Composite Filter Diffusion rate (mol/s/molfrac) x Mol fraction

Compound	Molecular Weight MW, g/mol	Carbon Composite Filter Diffusion Rate[1,2] DF, mol/s/molfrac	Maximum Weighted Avg Drum Headspace Conc.[3] ppmv	Molfraction (MF) molfrac	Avgerage Drum Emission Rate ADE, mol/s/drum	SOPE ug/m^3	35 Year Health-based Limit ug/m^3	70 Year Health-based Limit ug/m^3
Carbon tetrachloride	153.84	1.21E–06	2137.67	2.14E–03	2.59E–09	1.77E–02	1.33E–01	6.70E–02
1,1,1–Trichloroethane	133.42	1.30E–06	1665.44	1.67E–03	2.17E–09	1.29E–02	1.25	6.25E–01

NOTE:
[1] From Table D9–1, Appendix D9, carbon tetrachloride
[2] Estimated for 1,1,1–Trichloroethane
[3] From Table 5

TABLE 8 – Maximum Public Exposure Concentration at the LWB from Underground Waste Emissions From a Single Closed Waste Panel

Assumptions:

83432.6 = X = Number of drums per panel, calculated based upon volume of panel and drums

0.000107 = ADF_{CT} = Air Dispersion Factor, from Table D9–3, Appendix D9, Carbon tetrachloride

0.000107 = ADF_{TCA} = Air Dispersion Factor, from Table D9–3, Appendix D9, 1,1,1–Trichloroethane

425000 = V = Total mine ventilation rate, ft^3/min, from Table D9–3, Appendix D9

0.1 = GR = Best estimate average gas generation rate, mol/drum/yr, from Table D9–3, Appendix D9, Brush 1991

2.1 = GR_h = Best estimate maximum gas generation rate under humid conditions, mol/drum/yr, Brush 1991

5 = GR_i = Assumed gas generation rate under partially inundated conditions, mol/drum/yr, Brush 1991

0.4 = VGR = Equivalent gas generation rate due to creep, mol/drum/yr, from Table D9–3, Appendix D9

Formulae:

$$\text{SCPE} = \text{single closed panel emissions} = \frac{(ADF) \times (MF) \times [(GR) + (VGR)] \times (X) \times (MW) \times (10^6 \text{ ug/g})}{(525960 \text{ min/yr}) \times (V) \times (0.0283 \text{ m}^3/\text{ft}^3)}$$

$$\text{Molfraction} = \frac{(\text{Max Weighted Avg Drum Headspace Conc})}{(\text{molfraction}/10^6 \text{ ppmv})}$$

Compound	Molecular Weight MW, g/mol	Max Weighted Avg Drum Headspace Conc[1] ppmv	Molfraction MF molfrac	Gas Generation Rates mol/drum/yr	SCPE ug/m^3	35 Year Health–based Limit ug/m^3	70 Year Health–based Limit ug/m^3
Carbon tetrachloride	153.84	2137.67	2.14E–03	GR = 0.1	2.32E–04	1.33E–01	6.70E–02
				GR_h = 2.1	1.16E–03		
				GR_i = 5.0	2.51E–03		
1,1,1–Trichloroethane	133.42	1665.44	1.67E–03	GR = 0.1	1.57E–04	1.25	6.25E–01
				GR_h = 2.1	7.84E–04		
				GR_i = 5.0	1.69E–03		

NOTE:
[3] From Table 5

TABLE 9 – Maximum Occupational Exposure From Underground Emissions: 1 Panel with 2 Rooms Closed, 4 Rooms Filled and Open, and 1 Open Working Room

Assumptions:

From Table D9-1, Appendix D9:

47000 = V = total panel ventilation rate, ft^3/min (2000 each of 6 filled rooms, 35000 working room)
4000 = V = closed room x 2, ft^3/min
8000 = V = open room x 4, ft^3/min
35000 = V = working room x 1, ft^3/min

83432.6 = X = calculated total number of drums per panel, based on volume
23837.89 = X_{closed} = 2/7(83432.6) drums in the two closed rooms
47675.77 = X_{open} = 4/7(83432.6) drums in the four open rooms
11918.94 = $X_{working}$ = 1/7(83432.6) drums in the working room
0.00153 = MF_{CT} = mol fraction, from Table 6, Carbon tetrachloride
0.00122 = MF_{TCA} = mol fraction, from Table 6, 1,1,1-Trichloroethane
0.1 = GR = best estimate average gas generation rate, mol/drum/yr, Table D9-3, Appendix D9, Brush 1991
2.1 = GR_h = maximum gas generation under humid conditions, mol/drum/yr, Brush 1991
5 = GR_i = assumed gas generation rate under parially inundated conditions, mol/drum/yr, Brush 1991
0.4 = VGR = gas generation rate due to creep, mol/drum/yr, from Table D9-3, Appendix D9
153.84 = MW_{CT} = molecular weight, g/mol, from Table 1, Carbon tetrachloride
133.42 = MW_{TCA} = molecular weight, g/mol, 1,1,1- Trichloroethane
2.59E-09 = ADE_{CT} = average drum emission rate, mol/s/drum, from Table 6, Carbon tetrachloride
2.17E-09 = ADE_{TCA} = average drum emission rate, mol/s/drum, from Table 6, 1,1,1-Trichloroethane

Formulae:

$$SCPE = \frac{(MF) \times [(GR) + (VGR)] \times (MW) \times (X) \times (10^6 ug/g)}{(525960 min/yr) \times (V) \times (0.0283 m^3/ft^3)}$$

$$SOPE_{open/working\ room} = \frac{(X) \times (ADE) \times (MW) \times (10^6 ug/g)}{(V) \times (0.0283\ m^3/ft^3) \times (min/60s)}$$

compound	Gas Generation mol/drum/yr	SCPE, 2 rooms ug/m^3	SOPE, 4 rooms ug/m^3	SOPE, 1 working ug/m^3	Total Panel Emissions, ug/m^3	Total Panel Emissions, ppmv	OSHA 8-hr PEL ppmv
Carbon tetrachloride	GR = 0.1	4.71E+01	5.03E+03	2.88E+02	5.37E+03	0.84	10
	GR_h = 2.1	2.36E+02	5.03E+03	2.88E+02	5.56E+03	0.87	10
	GR_i = 5.0	5.09E+02	5.03E+03	2.88E+02	5.83E+03	0.91	10
1,1,1-Trichloroethane	GR = 0.1	3.26E+01	3.66E+03	2.09E+02	3.90E+03	0.61	10
	GR_h = 2.1	1.63E+02	3.66E+03	2.09E+02	4.03E+03	0.63	10
	GR_i = 5.0	3.52E+02	3.66E+03	2.09E+02	4.22E+03	0.66	10

APPENDIX A
SUMMARY OF CALCULATIONS AND TABLES

The information provided in this appendix explains the specific calculations performed to derive the values presented in Tables 5-9 of the Sensitivity Analysis.

1. TABLE 5 - Maximum Weighted Average Drum Headspace Concentration

The Waste Matrix Code Groups (WMCG) were ranked based upon the highest average concentrations for the selected VOCs (carbon tetrachloride and 1,1,1-trichloroethane). The total volume of available waste for each WMCG was obtained from the 1995 WIPP TRU BIR. It was then assumed that a hypothetical panel would be filled with a worst-case waste composition. The volume of the WMCG with the highest concentration of carbon tetrachloride and 1,1,1-trichloroethane was subtracted from the total panel volume. The WMCG with the second highest concentration of VOC was subtracted out and so forth until the entire panel was filled with waste. For both carbon tetrachloride and 1,1,1-trichloroethane, waste from only two WMCGs were required to fill the panel. For carbon tetrachloride, the entire available volume of solidified organic waste and a partial volume of combustible waste was required to compose the hypothetical panel fill. For 1,1,1,-trichloroethane, the entire available volume of solidified organic waste and a partial volume of heterogeneous waste was required to fill the hypothetical worst-case scenario panel. These volumes were converted into drum equivalents by dividing the volume in cubic meters by the volume of one drum (0.208 m^3). The corresponding volumes, in both cubic meters and drum equivalents, of the WMCGs for both VOCs are listed in the table.

The second step was to determine the maximum weighted average drum headspace concentration of carbon tetrachloride and 1,1,1-trichloroethane for each drum in a single disposal panel, using equation (1) below. This was done by first multiplying the average drum headspace concentration of VOC per WMCG (VOC) by the maximum drum equivalent in a panel for the WMCG (MDE), which resulted in the total concentration of VOC in a panel per WMCG. The average concentrations were determined in Table 1, carbon tetrachloride, and Table 3, 1,1,1-trichloroethane. The maximum drum equivalents of a WMCG in a panel were obtained using the methods stated in the above paragraph.

The next step was to sum the maximum drum equivalents per WMCG per panel and to sum the total concentrations of VOC per WMCG per panel, to determine overall panel drum equivalents and concentrations. The sum of the total concentration of VOC in a panel was then divided by the total sum of the maximum drum equivalents per WMCG per panel. The result is the maximum weighted average drum headspace concentration (MWADHC) for each VOC.

$$MWADHC = \frac{\sum_{n=1}^{n} [(VOC) x (MDE)]}{\sum_{n=1}^{n} (MDE)} \qquad (1)$$

where:

MWADHC = maximum weighted average drum headspace concentration, ppmv
VOC = average VOC concentration per WMCG per panel, ppmv
MDE = maximum drum equivalents per WMCG per panel
n = number of WMCGs

2. TABLE 6 - Maximum Occupational Exposure From Underground Emissions

After determining the maximum weighted drum headspace concentration per panel for both carbon tetrachloride and 1,1,1-trichloroethane, the maximum occupational exposure from underground waste emissions could be calculated. The maximum single open panel exhaust concentration (SOPE), or maximum occupational exposure from waste/VOC emissions was calculated using equation (2), below:

$$SOPE = \frac{[(X) x (ADE) x (MW) x (10^6 \mu g/g)]}{[(V) x (0.0283 m^3/ft^3) x (\min/60 s)]} \qquad (2)$$

where:

SOPE = Single open panel exhaust concentration from waste emissions, ppmv
X = number of drum equivalents per panel, based upon volume
ADE = average drum emission rate, mol/s/drum
MW = molecular weight, g/mol
V = panel ventilation rate, ft^3/min

and where the average drum emission rate (ADE) is determined using equations (3) and (4), as follows:

$$ADE = (MF) \times (CCFD) \tag{3}$$

where:

MF = molfraction
CCFD = carbon composite filter diffusion rate, mol/s/molfraction

and

$$Molfraction = [(MWADHC) \times (\frac{molfraction}{10^6 ppmv})] \tag{4}$$

The result of equation (2) is the emissions in $\mu g/m^3$. The OSHA 8-hour permissible exposure limits (PELs) are given in units of ppmv. In order to compare the calculated maximum panel exhaust concentration from waste emissions to the PELs, a units conversion must be determined. Table D9-1 states that the conversion from $\mu g/m^3$ to ppmv is by the following formula:

$$ppmv = \frac{(\mu g/m^3) \times (0.024)}{(MW)} \tag{5}$$

This formula appears to be the result of simplification of the formula presented in Appendix VOC of the May 31, 1995 version of the WIPP No Migration Variance Petition (NMVP). The equation in the NMVP is as follows:

$$HS_c = HS x 10^{-6} (molfraction/ppmv) x \frac{PxMW}{RxT} x 10^6 (\mu g/g) x 10^3 L/m^3 \quad (6)$$

where:

HS = average drum headspace concentration, μg/m^3
P = pressure, 1 atm
MW = molecular weight, g/mol
R = ideal gas constant, 0.082057 L-atm/mol-K
T = temperature, 298 K
HS_c = average drum headspace concentration, ppmv

Rearranging the above equation and simplifying the constant terms results in equation (5).

3. TABLE 7 - Maximum Public Exposure Concentration at the LWB from Underground Waste Emissions From a Single Open Waste Panel, and TABLE 8 - Maximum Public Exposure Concentration at the LWB from Underground Waste Emissions From a Single Closed Waste Panel

For the calculation of the maximum public exposure concentration at the Land Withdrawal Boundary (LWB) due to underground waste emissions, the formulas as presented in Table D9-3, Appendix D9 of the permit application were applied in these calculations. All of the terms in the equations for determining both emissions due to a single open panel and a single closed panel have been previously explained in this paper and in Tables 5 and 6, with the exception of the air dispersion factor.

The air dispersion factor (ADF) is the result of the air dispersion modeling undertaken in Chapter 5 of the May 31, 1995 version of the WIPP No Migration Variance Petition (NMVP). The model ISCS2 was used to determine this factor. Since time and information was not available to review the modeling procedures followed in determining this factor, it will be assumed that the values used for the air dispersion term is acceptable.

For estimating the emission due a single open panel, the following equation was applied:

$$SOPE = \frac{(X) x (ADF) x (ADE) x (MW) x (10^6 \mu g/g)}{(V) x (0.0283 m^3/ft^3) x (min/60s)} \quad (9)$$

Equation number (10) below represents the method for estimating the emissions from a single closed panel.

$$SCPE=\frac{(ADF)\,x\,(MF)\,x\,[\,(GR)+(VGR)\,]\,x\,(X)\,x\,(MW)\,x\,(10^{6}\mu g/g)}{(525960\mathrm{min}/yr)\,x\,(V)\,x\,(0.0283m^{3}/ft^{3})} \qquad (10)$$

The emissions from these calculations were compared to both a 35- and 70-year health-based limit, although the permit application only used a 35-year health-based risk. Both the 35- and 70-year health-based limits were calculated based upon modified methodologies as presented in Chapter 5, Section 5.1.3 Methodology for Determining Health-Based Levels, of the WIPP NMVP. Since both carbon tetrachloride and 1,1,1-trichloroethane are carcinogens, the carcinogenic health-based limit formula was applied. The NMVP presents the formula using an absorption factor (AF). This is incorrect, as absorption factors are only applied in determining the effects/limits from soil and dermal exposures. Instead of the absorption factor, the formula should contain an exposure time in the denominator. The formula, as modified, applied in determining the health-based limits is as follows:

$$HBL=\frac{TRLxAT}{EFxEDxURFxET} \qquad (11)$$

where:

HBL = health-based limit, carcinogenic, $\mu g/m^3$
TRL = target risk level
= 10^{-6}, Carbon tetrachloride (class B2 carcinogen)
= 10^{-5}, 1,1,1-Trichloroethane (class C carcinogen)
AT = averaging time, days
EF = exposure frequency, days/year
ED = exposure duration, years
URF = unit risk factor, $(\mu g/m^3)^{-1}$
ET = exposure time, hour/day

For the averaging time, exposure frequency and exposure duration, the EPA recommended standard default parameters were used. Averaging time for carcinogens is assumed to 70 years at 365 days per year which equals 25,550 days. Exposure duration was 35 years for the 35-year health-based limit and 70 years for the 70-year health-based limit calculation. The exposure time was conservatively assumed to be 24 hours per day.

4. TABLE 9 - Maximum Occupational Exposure From Underground Emissions: 1 Panel with 2 Rooms Closed, 4 Rooms Filled and Open, and 1 Open Working Room

Table 9 presents the calculations for determining the maximum exposure from underground emissions in a worst-case scenario. It was assumed that a panel was near completion of having every room filled. Two rooms were assumed closed and to have been affected by salt creep. Four rooms were considered filled, but open and the last room of the panel was assumed to be a filled working room.

The panel ventilation rates for the rooms were taken from Table D9-1 of Appendix D9 of the permit application. Table D9-1 states that the overall panel ventilation rate is 47,000 ft^3/min with each room having a ventilation rate of 2000 ft^3/min with the exception of the working room which has a ventilation rate of 35,000 ft^3/min. Thus, for the two closed rooms, an overall ventilation rate was assumed to be 4000 ft^3/min (2 rooms x 2000 ft^3/min). For the four open rooms, a rate of 8000 ft^3/min (4 rooms x 2000 ft^3/min) was assumed and the working room was assumed to be ventilated at the rate of 35,000 ft^3/min.

In the permit application, the overall volume of a panel was assumed to be 17,354 m^3. The typical drum emplaced in a panel has a volume of 55-gal, or 0.208 m^3. Dividing the panel volume by the volume of a drum results in the overall drum equivalents, in volume, for a panel, which was determined to be 83432.6 m^3. It was then assumed that each of the seven rooms of a panel represents one-seventh of the overall panel volume. The drum equivalents for the two closed rooms was determined from two-sevenths of the panel volume, the four open rooms, four-sevenths of the panel volume, and the working room, one-seventh of the panel volume.

The gas generation rate terms for the average gas generation rate and the gas generation rate due to creep were taken from Table D9-3 of Appendix D9 of the permit application and from Brush's 1991 gas generation studies. The best estimate average gas generation rate (GR) was assumed to be 0.1 mol/drum/yr, which was assumed in both the permit application and in Brush's studies. For comparison and sensitivity analysis of the gas generation rate on overall calculations of emissions, two other gas generation rates were selected for analysis. A rate of 2.1 mol/drum/yr, from Brush 1991, represented the maximum gas generation rate under humid conditions GR_h). A rate of 5.0 mol/drum/yr, also from Brush 1991, was selected to represent gas generation rates under partially inundated conditions (GR_i). Brush stated that under fully inundated conditions, gas generation would be at the rate of 7.0 mol/drum/yr. An average of the totally inundated conditions and noninundated conditions was performed to represent the gas generation under partially inundated conditions, for the calculations. Gas generation due to creep (VGR) was transcribed from the permit application.

The values for molfraction and average drum emission rate for both carbon tetrachloride and 1,1,1-trichloroethane were previously determined in the calculations of Table 5. See the text for Table 5 for explanation of these parameters.

The formula for calculating the emission rate from the two closed rooms was adapted form Table D9-3 of Appendix D9. The air dispersion factor was omitted from the equation as the goal of the calculation was to determine emissions at a panel seal. The equation is as follows:

$$SCPE_{2rooms}=\frac{(MF)\,x\,[\,(GR)+(VGR)\,]\,x\,(MW)\,x\,(X)\,x\,(10^{6}\mu g/g)}{(525960min/yr)\,x\,(V)\,x\,(0.0283m^{3}/ft^{3})} \qquad (7)$$

The equation for estimating the emissions from the open and working rooms was adapted from Table D9-3 of Appendix D9. Again the air dispersion factor was omitted from the equation. The formula applied is as follows:

$$SOPE_{open/workingroom}=\frac{(X)\,x\,(ADE)\,x\,(MW)\,x\,(10^{6}\mu g/g)}{(V)\,x\,(0.0283m^{3}/ft^{3})\,x\,(min/60s)} \qquad (8)$$

A basic assumption must be made that the above equations as modified from Appendix D9 are correct as modified to be applied to this scenario.