

**A WEST VALLEY DEMONSTRATION PROJECT MILESTONE -  
ACHIEVING CERTIFICATION TO SHIP WASTE TO THE NEVADA TEST SITE**

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**ABSTRACT**

The West Valley Demonstration Project (WVDP) has successfully pretreated and vitrified nearly all of the 600,000 gallons of liquid high-level radioactive waste that was generated at the site of the only commercial nuclear fuel reprocessing plant to have operated in the United States. Low-level waste (LLW) generated during the course of the cleanup effort now requires disposal.

Currently the WVDP only ships Class A LLW for off-site disposal. It has been shipping Class A wastes to Envirocare of Utah, Inc. since 1997. However, the WVDP may also have a future need to ship Class B and Class C waste, which Envirocare is not currently authorized to accept. The Nevada Test Site (NTS), a U.S. Department of Energy (DOE) facility, can accept all three waste classifications. The WVDP set a goal to receive certification to begin shipping Class A wastes to NTS by 2001. Formal certification/approval was granted by the DOE Nevada Operations Office on July 12, 2001.

This paper discusses how the WVDP contractor, West Valley Nuclear Services Company (WVNSCO), completed the activities required to achieve NTS certification in 2001 to ship waste to its facility. The information and lessons learned provided are significant because the WVDP is the only new generator receiving certification based on an NTS audit in January 2001 that resulted in no findings and only two observations—a rating that is unparalleled in the DOE Complex.

This work was performed under Contract No. DE-AC24-81NE44139.

**INTRODUCTION - HISTORY OF THE WEST VALLEY DEMONSTRATION PROJECT**

The West Valley Demonstration Project (WVDP) is an environmental nuclear waste management project being conducted by the U.S. Department of Energy (DOE) in cooperation with the New York State Energy Research and Development Authority (NYSERDA). The Project is located at the site of the only commercial nuclear fuel reprocessing facility to have operated in the United States. The mission of the WVDP is, among other things, to solidify the high-level radioactive waste left at the site from the original nuclear fuel reprocessing activities, develop suitable containers for holding and transporting the solidified waste to a federal repository, dispose of any Project low-level and transuranic waste, and decontaminate and decommission the Project facilities.

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The WVDP site is owned by the State of New York and operated for DOE by the West Valley Nuclear Services Company (WVNSCO), the prime contractor at the site.

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## **BACKGROUND**

In FY2001, the WVDP had a milestone that stated:

Perform all necessary activities including document preparation, assessment, certification, etc., in order to be prepared to ship low-level waste (LLW) to the Nevada Test Site (NTS) for disposal. Ship a minimum of 700 cubic feet of LLW for disposal at the NTS by September 30, 2001.

To achieve that goal, a complete characterization and certification program had to be developed and implemented to successfully pass an audit by the NTS. The program had to demonstrate, with objective evidence, that the WVDP was in full compliance with the NTS Waste Acceptance Criteria (WAC). In order to accomplish this, there were proactive engagements with the WVNSCO Quality Assurance (QA) organization. QA was requested to perform an audit on the existing procedures and documents against the requirements of the NTS WAC. QA completed the audit in December, 2000 and all items associated with the audit were closed out by January 21, 2001. This action identified and corrected noted deficiencies in the WVDP program prior to the NTS audit. An additional item that assisted the WVDP was attendance at the NTS Users Group meetings, supported by the National Nuclear Security Administration/Nevada Operations Office (NNSA/NV). The Users Group meetings allowed numerous opportunities to ask questions, exchange technology, and transfer ideas and problem solving solutions among the attendees.

The WVDP had been shipping LLW to a commercial facility (Envirocare of Utah) since 1997. WVDP waste profiles included slightly contaminated personal protection equipment (PPE), herculite, soil, and dewatered resin from the Wastewater Treatment Facility. Envirocare is currently licensed to accept Class A radioactive waste. However, the radiological limitations of the Envirocare radioactive license necessitated expanding the disposal capability of the WVDP.

## **PROGRAM DEVELOPMENT**

The WVDP had processes in place that provided the analytical data necessary to develop a waste profile to meet the Envirocare WAC. The WVDP also had detailed shipping procedures that ensured waste package "characterization" was within tolerance of the approved waste profile. However, the WVDP lacked an integrated program and the resultant procedures to document this process.

Most WAC requirements can be placed in the following four categories:

- Controls on waste characterization
- Specific waste packaging requirements
- Certifications and approvals required prior to shipping waste
- Quality Assurance/Quality Control requirements.

The WVDP program development encompassed three major attributes: strong waste characterization processes; traceability from generation to disposal; and compliance with all applicable rules, regulations, and waste acceptance criteria.

The cornerstone of a waste disposition program, either to a commercial or DOE facility, is radiological and Resource Conservation and Recovery Act (RCRA) characterization. The WVDP was especially challenged in developing the radiological portion of the waste characterization due to the previous commercial fuel reprocessing activities that took place from 1966 to 1972.

## **RADIOLOGICAL CHARACTERIZATION AT THE WVDP**

Due to the nature of radiological contaminants and the history of the former commercial Nuclear Fuel Services (NFS) site, characterization of radiological wastes presents both unique issues and challenges that may not be evident at most DOE sites. These issues and challenges apply to wastes that were generated during previous cleanup efforts, as well as current and future decommissioning activities.

Radiological characterization at many DOE sites often begins with process knowledge, in which detailed information about a particular product or process is established and documented (e.g., concentration of major and trace radionuclides in the heat-source grade plutonium at the Mound plant). The baseline of radiological process knowledge at the WVDP is very limited. One area where the site had established substantial process knowledge is with the vitrification process. Samples and analyses for sludge, slurry, and glass created the base information that is being used for vitrification and in Vitrification Expended Materials Processing (VEMP), a program in place to disposition expended material from the Vitrification Facility. For most of the core original NFS facilities, however, this base information is missing and unknown.

This is due to the original mission of the NFS site, which was to reprocess spent commercial fuel through a series of separation steps to recover uranium and plutonium. The isotopic make-up of the spent fuel was not consistent; low burn-up fuel, unirradiated fuel, mid burn-up fuel, different uranium enrichments, and even thorium-based fuel assemblies were all processed. This resulted in waste items with a high variability in the proportions of radionuclides. The NFS processes themselves chemically separated some radionuclides from others. Since NFS did not characterize or document the exact proportions of many of the radionuclides in the different intermediate and final waste streams, this knowledge is essentially absent for much of the original NFS materials.

Typically, many DOE sites handled and processed materials with known radiological parameters, (i.e., detailed Military Specification [MilSpec] types of material or radionuclides that were highly controlled and/or uniformly distributed), or the sites did not do chemical separations that drastically changed the radiological characteristics of the waste. Other sites (e.g., Savannah River, Hanford, Idaho) had the same processes as NFS (i.e., reprocessing spent fuel) but the types of fuels that were processed were much more consistent. Similar to the WVDP, millions of dollars have been put into the characterization of wastes from these processes. At the WVDP, the two high-level waste (HLW) tanks were directly sampled and analyzed. At Savannah River, work is under way on the 50 HLW tanks, and likewise at Hanford on the 173 HLW tanks. While these analyses are in support of vitrification at those sites, WVDP is the first site to address major radiological characterizations associated with decontamination and decommissioning (D&D) efforts of the core reprocessing facility (see Exhibit A).

With no sitewide radioisotopic “inventory” available, many waste items must be treated as unknowns until analytical data, combined with process knowledge, can determine a degree of certainty in the characterization. To satisfy off-site disposal facility criteria (e.g., NTS or the Waste Isolation Pilot Plant [WIPP]), the WVDP must invest in much upfront characterization effort. Currently, work is under way to characterize individual areas, and subareas within those zones, to ensure that wastes with the same type of radiological “fingerprints” are handled together. In turn, this knowledge will be used to support radiological characterization for some of the legacy wastes that were generated during past cleanup efforts.

The work on the high-level radioactive waste cleanup process has helped the WVDP push forward toward the decommissioning of the vitrification process itself. For other core portions of the WVDP, efforts are under way to characterize ongoing D&D wastes. This eases the effort for future D&D wastes and provides information that can be used to characterize previously generated legacy waste from these areas.

## **SCHEDULE**

The major program documents that were developed defined the top-down approach to implementing the NTS WAC. First, a gap analysis was performed on the existing WVDP program against the NTS WAC. Areas became apparent that needed to be enhanced: 1) an on-site storage WAC was clearly defined to ensure that radioactive waste was generated, handled, segregated, packaged, and stored in a safe and efficient manner 2) detailed waste characterization procedures needed development 3) a Waste Certification Program Plan and implementing procedures were developed and (3) all subsequent “down stream” documents were reviewed and revised to ensure consistency and integration of the program. A total of more than 90 documents were either developed or revised as a result of this effort.

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A Quality Assurance audit was requested to review the program. The audit was conducted from November 27 through December 5, 2000. The internal audit identified five noteworthy practices, two findings, and three requirement non-compliances. All issues were addressed for the findings and non-compliances and were closed out by January 22, 2001. The audit was very important in that it “self-identified” items that could be addressed prior to the official audit by NTS, which was scheduled for February 2001.

In January 2001, NTS requested to perform the audit two weeks earlier than scheduled. The WVDP accepted and the audit was performed the week of January 22, 2001. The result of the audit was no findings and only two observations—unparalleled in the DOE Complex for new generators. The WVDP responded to the audit report and NTS formally approved the program and two waste profiles on July 12, 2001. On July 27, 2001, 703 cubic feet of LLW was shipped to NTS, two months ahead of schedule.

**Exhibit A**

Radiological Technical Basis Document (TBD)

for Low-Level Waste Stream

Vitrification Expended Material Program (VEMP) Debris

## **TECHNICAL BASIS FOR RADIOLOGICAL PROPERTIES ASSOCIATED WITH THE VEMP AIRBORNE WASTE STREAM**

### **1.0 Purpose**

This Technical Basis Document (TBD) is intended to provide justification for radionuclide properties associated with low-level waste (LLW) generated from the Vitrification Expanded Materials Program (VEMP). This TBD addresses waste materials that have been incidentally contaminated from VEMP operations due to airborne deposition of volatilized radionuclides resulting from high-level waste vitrification activities. Specifically, this TBD supports the radionuclide properties associated with the waste stream profile, including:

- isotopes of concern
- radioisotopic activity ranges
- representative final waste form activity
- transuranic nuclide data
- enriched uranium data.

It should be noted that the data supplied by the RADMAN® computer program, analysis of multiple sample data sets, and/or actual sampling data for the VEMP airborne waste stream is needed to support this technical basis and should be included in the data file.

### **2.0 Isotopes of Concern**

Radionuclides associated with the VEMP airborne LLW stream have been determined through radiochemical sampling and gamma spectroscopy. Based on this sampling effort, 30 radionuclides were initially identified as isotopes of concern. After considering the high-activity range for this waste stream, 13 of the initial 30 radioisotopes were dropped from reporting. This was warranted since the maximum concentration of these 13 radionuclides would be present below one percent of the action levels specified in DOE/NV-325 and below one percent of the total waste form activity. See Table IV-1 for a listing of these radionuclides.

### **3.0 Radioisotopic Activity Ranges**

The high- and low-activity ranges for the VEMP airborne waste stream are based on realistic bounding conditions. Radionuclide package concentrations are based on the RADMAN® dose-to-curie program, along with scaling factors developed using an established isotopic distribution. The low-activity range for this waste stream is based on the minimum practical exposure rate that is measurable for the hand-held meter (e.g., 100  $\mu\text{R/hr}$ ) in conjunction with the minimum mass loading allowed for an individual waste package.

Some of the waste generated during VEMP operations is considered potentially transuranic (TRU) waste and/or Greater-than-Class-C (GTCC) according to 10 CFR 61. Therefore, it is realistic to assume the high-activity range could be representative of levels close to these classifications.

### 3.1 Low-Activity Range

The minimum allowable waste mass for a 55-gallon drum is 50 kg. Inputting this mass, along with a minimum practical exposure rate of 100  $\mu\text{R/hr}$  and the isotopic distribution for the VEMP airborne waste stream, results in quantified radionuclide activities (RADMAN®). The isotopic activity output of the RADMAN® program applies to a 55-gallon drum (i.e., 0.208  $\text{m}^3$ ) and is in terms of mCi. Therefore, dividing these values by 0.208  $\text{m}^3/\text{drum}$  and multiplying by 3.7 E+07 Bq/mCi results in the low isotopic activity range for this waste stream. See Table IV-1 for a listing of these isotopic values.

### 3.2 High-Activity Range

In some cases, TRU and GTCC wastes are generated during VEMP waste operations. In these cases, TRU and/or GTCC wastes will be handled as suspect TRU waste, segregated from other LLW and stored at the Lag Storage System until a disposal option is available. Since DOE-defined TRU wastes are, by default, considered GTCC waste; and the VEMP airborne waste stream contains mixed fission, activation, and TRU isotopes; the GTCC criteria provides a bounding condition for the high-activity range.

VEMP airborne wastes are packaged in either 55-gallon drums (50 lbs empty) or B-25 waste boxes (655 lbs empty). Since the maximum weight limit for these packages is 1,200 lbs and 9,000 lbs, respectively, the maximum waste mass density equates to:

$$\text{55-gallon drum} - \frac{(1,200 \text{ lbs} - 50 \text{ lbs})}{0.208 \text{ m}^3/\text{drum}} = 5,528 \text{ lbs/m}^3 (2,500 \text{ kg/m}^3) \quad \text{Eq. 1}$$

$$\text{B-25 box} - \frac{(9,000 \text{ lbs} - 655 \text{ lbs})}{2.5 \text{ m}^3/\text{box}} = 3,338 \text{ lbs/m}^3 (1,514 \text{ kg/m}^3) \quad \text{Eq. 2}$$

As a conservative measure, since the 55-gallon drum can produce the highest waste mass density per cubic meter, it was used to establish the high-activity range for the waste stream profile. In order to determine the high-activity range based on the GTCC limit, the isotopic values provided in the Analysis of Multiple Sample Data Sets for VEMP airborne data were used as the starting point. Although these sampling values provide an arbitrary concentration, they indicate individual activity relationships with respect to each isotope. Using these values and dividing by



the respective GTCC limit, provides a ratio for each radionuclide. If unity is divided by the sum of the ratios, a factor is calculated that when multiplied by the original sampling activity, results in the high-activity range for each isotope. Table III-1 provides the GTCC concentration levels used for determining the high-activity range:

**Table III-1.**  
**Input Data for VEMP Airborne High-Activity Range<sup>a</sup>**

Isotope	GTCC Concentration		Isotope	GTCC Concentration	
	Ci/m <sup>b</sup>	Ci/drum <sup>c</sup>		Ci/m <sup>b</sup>	Ci/drum <sup>c</sup>
Carbon-14	8	1.66	Plutonium-241	3,500 <sup>b</sup>	3,500 <sup>b</sup>
Nickel-59	220	45.8	Curium-242	20,000 <sup>b</sup>	20,000 <sup>b</sup>
Technetium-99	3	0.62	Nickel-63	700	146
Iodine-129	0.08	0.017	Strontium-90	7,000	1,456
Alpha > 5 Years <sup>d</sup>	100 <sup>b</sup>	100 <sup>b</sup>	Cesium-137	4,600	975

- The values in Table III-1 were extracted from 10 CFR 61.55, Tables 1 and 2.
- In units of nanocuries per gram (nCi/g).
- Values determined by multiplying the volumetric concentration by 0.208m<sup>3</sup>/drum.
- To include alpha-emitting transuranium isotopes with half-lives greater than 5 years.

From the data provided in the Analysis of Multiple Sample Data Sets for VEMP Airborne data, maximum mass loadings, and Table III-1 above, the following algorithm is used to estimate the high-activity range:

$$X \left[ \frac{\left( \frac{7.68E-10 \text{Ci}_{C-14}}{1.66 \text{Ci/drum}} + \frac{1.03E-10 \text{Ci}_{Ni-59}}{45.8 \text{Ci/drum}} + \frac{4.47E-12 \text{Ci}_{Tc-99}}{0.62 \text{Ci/drum}} + \frac{7.74E-11 \text{Ci}_{I-129}}{0.017 \text{Ci/drum}} \right)}{\left( \frac{1.73E-8 \text{Ci}_{\alpha} \times 1E9 \text{nCi/Ci}}{5.0E5 \text{g} \times 100 \text{nCi/g}} + \frac{7.05E-9 \text{Ci}_{Pu-241} \times 1E9 \text{nCi/Ci}}{5.0E5 \text{g} \times 3,500 \text{nCi/g}} \right)} + \frac{\left( \frac{1.42E-10 \text{Ci}_{Cm-242} \times 1E9 \text{nCi/Ci}}{5.0E5 \text{g} \times 20,000 \text{nCi/g}} + \frac{3.16E-9 \text{Ci}_{Ni-63}}{146 \text{Ci/drum}} + \frac{4.54E-7 \text{Ci}_{Sr-90}}{1456 \text{Ci/drum}} + \frac{1.31E-6 \text{Ci}_{Cs-137}}{957 \text{Ci/drum}} \right)}{\right]} = 1$$

Eq. 3. Solving for X = 2.8E6 (correction factor for a drum)

This value can now be used to develop the high-activity range with the following equation:

$$C_{(i)} (\text{Bq/m}^3) = \frac{(\text{Act}_{\text{Iso}} (\text{Ci}) \times 2.8\text{E}6_{\text{factor}} (\text{drum}) \times 3.7\text{E}10 (\text{Bq/Ci}))}{0.208\text{m}^3 / \text{drum}} \quad \text{Eq. 4}$$

Where:

- $C_{(i)}$  = High-activity concentration of isotope (i) in  $\text{Bq/m}^3$   
 $\text{Act}_{\text{Iso}}$  = Arbitrary radionuclide concentration taken from the Analysis of Multiple Sample Data Sets (Ci)  
 $2.8\text{E}6$  = Factor relating the Data Set value to the high-activity range on a drum basis.

Using the equation above results in the high-activity range for VEMP airborne radionuclides as illustrated in Table IV-1.

#### 4.0 Representative Final Waste Form Activity

While several VEMP airborne waste packages have been generated to date, only two have been properly characterized as LLW. This LLW was packaged in B-25 containers and have relatively low-activity values. The attached output from RADMAN® was used in the development of the final waste form activity using the geometric average of the activities in the two waste packages. In this case, the output in terms of mCi, was multiplied by  $3.7\text{E}7 \text{ Bq/mCi}$  and divided by  $2.5 \text{ m}^3/\text{container}$ . These results are tabulated in Table IV-1.

Using the equations and assumptions provided in Sections 3.1 and 3.2, the activity ranges and final waste form activities have been calculated and provided in Table IV-1.

**Table IV-1.**  
**Low-and High-Activity Ranges, and Representative Final Waste Form**  
**Activity Associated with VEMP Airborne Wastes**

Isotope	Low-Activity Range (Bq/m <sup>3</sup> )	High-Activity Range (Bq/m <sup>3</sup> )	Final Waste Form Activity (Bq/m <sup>3</sup> )
H-3 <sup>a</sup>	2.8E+01	1.9E+06	7.7E+02
C-14	5.5E+03	<b>3.8E+08</b>	1.5E+05
Fe-55 <sup>a</sup>	1.4E+04	9.4E+08	3.9E+05
Ni-59 <sup>a</sup>	7.6E+02	5.1E+07	2.1E+04
Co-60 <sup>a</sup>	1.7E+03	1.2E+08	4.7E+04
Ni-63 <sup>a</sup>	2.3E+04	1.6E+09	6.3E+05
Sr-90	3.2E+06	2.3E+11	8.8E+07

Isotope	Low-Activity Range (Bq/m <sup>3</sup> )	High-Activity Range (Bq/m <sup>3</sup> )	Final Waste Form Activity (Bq/m <sup>3</sup> )
Tc-99 <sup>a</sup>	3.2E+01	2.2E+06	8.8E+02
I-129	5.5E+02	3.8E+07	1.5E+04
Cs-137	9.4E+06	<b>6.5E+11</b>	2.6E+08
Pm-147 <sup>a</sup>	1.0E+05	6.9E+09	2.8E+06
Eu-154 <sup>a</sup>	2.5E+04	1.8E+09	6.9E+05
U-232	1.5E+03	1.0E+08	4.1E+04
U-233 <sup>a</sup>	3.5E+01	2.4E+06	9.6E+02
U-234 <sup>a</sup>	1.2E+01	8.3E+05	3.3E+02
U-235 <sup>a</sup>	1.2E+00	8.3E+04	3.3E+01
U-236 <sup>a</sup>	2.8E+00	1.9E+05	7.7E+01
U-238 <sup>a</sup>	8.9E+00	6.1E+05	2.4E+02
Pu-238	5.6E+03	3.8E+08	1.5E+05
Pu-239	1.5E+03	9.9E+07	4.1E+04
Pu-240	1.0E+03	6.9E+07	2.8E+04
Pu-241	5.2E+04	3.5E+09	1.4E+06
Pu-242	8.2E+01	5.6E+06	2.3E+03
Np-237	2.5E+01	1.7E+06	6.9E+02
Am-241	5.2E+04	3.5E+09	1.4E+06
Am-243	4.3E+03	2.9E+08	1.2E+05
Cm-242	1.0E+03	7.1E+07	2.8E+04
Cm-244	1.8E+04	1.2E+09	5.0E+05
Cm-245	4.0E+04	2.7E+09	1.1E+06
Cm-246	6.5E+03	4.4E+08	1.8E+05

- a. These radionuclides are not required to be reported since they would exist either below one percent of the NTS Action Level (Table E-1 of DOE/NV-325) and below one percent of the total activity concentration.
- b. Bolded values represent radionuclide concentrations that exceed Table E-1 of DOE/NV-325.

## 5.0 Transuranic Nuclide Data

There are several transuranic radionuclides associated with the VEMP airborne waste stream that warrants further attention. In particular, this waste stream has a total of 9 transuranium isotopes that are considered in this section. In determining the activity ranges and final waste form activities, methodology similar to that in Section 3.0 are followed, with one exception.

The low TRU activity range is based on the data and assumptions used in Section 3.1. The TRU final waste form activity is based on the data and assumptions made in Section 4.1. However, in development of the high TRU activity range (Section 3.2), the lowest waste mass, instead of the maximum, was used. This allows for maximizing the TRU radionuclide concentration on a mass basis.

### 5.1 Low TRU Activity Range and TRU Activity Representative of the Final Waste Form

Using the data provided in Table IV-1 for the low-activity range, along with the maximum mass for a given waste container (i.e., 500 kg/drum), the low TRU activity range can be calculated. Similarly, the final waste form activity is calculated using the final waste form activity from Table IV-1 using an average waste mass for the two waste containers as illustrated in Table V-1.

### 5.2 High TRU Activity Range

In Section 3.2, the high-activity range for radionuclides associated with the VEMP airborne waste stream was developed by calculating a drum correction factor that related maximum isotopic activities to the sum of fractions equal to unity against the GTCC limits. This correction factor was based on assuming the maximum allowable mass in a drum, thus maximizing the transuranic concentration on a volumetric basis. However, this methodology does not maximize the transuranic concentration on a mass basis. For this reason, the high TRU activity range is developed by calculating a drum correction factor associated with the lowest waste mass allowed in a drum (i.e., 50 kg or 5E4 g). Substituting this mass for the maximum mass in the equation illustrated in Section 3.2 results in the following algorithm:

$$X \left[ \frac{(7.68E - 10Ci_{C-14})}{1.66Ci / drum} + \frac{(1.03E - 10Ci_{Ni-59})}{45.8Ci / drum} + \frac{(4.47E - 12Ci_{Tc-99})}{0.62Ci / drum} + \frac{(7.74E - 11Ci_{I-129})}{0.017Ci / drum} + \frac{(1.73E - 8Ci_{alpha} \times 1E9nCi / Ci)}{(5.0E4g \times 100nCi / g)} + \frac{(7.05E - 9Ci_{Pu-241} \times 1E9nCi / Ci)}{5.0E4g \times 3,500nCi / g} + \frac{(1.42E - 10Ci_{Cm-242} \times 1E9nCi / Ci)}{5.0E4g \times 20,000nCi / g} + \frac{(3.16E - 9Ci_{Ni-63})}{146Ci / drum} + \frac{(4.54E - 7Ci_{Sr-90})}{1456Ci / drum} + \frac{(1.31E - 6Ci_{Cs-137})}{957Ci / drum} \right] = 1$$

Eq. 5

In this case,  $X = 2.85 \text{ E5}$  (The correction factor for the drum.)

From the data provided in the Analysis of Multiple Sample Data Sets for VEMP Airborne data, and assuming a waste mass of 50 kg, the high TRU activity range can be calculated for each isotope using the following equation:

$$C_{\text{TRU}} (\text{nCi/g}) = \frac{(\text{Act}_{\text{Iso}} (\text{Ci}) \times 2.85 \text{ E5}_{\text{factor}} (\text{drum}) \times 1 \text{ E9} (\text{nCiCi}))}{5 \text{ E4g} (\text{drum})} \quad \text{Eq. 6}$$

Where:

- $C_{\text{TRU}}$  = High activity concentration of each TRU isotope in nCi/g  
 $\text{Act}_{\text{Iso}}$  = Arbitrary radionuclide activity taken from the Analysis of Multiple Sample Data Sets (Ci)  
 $2.85 \text{ E5}$  = Factor relating the Data Set value to the high TRU activity range on a drum basis  
 $5 \text{ E4}$  = Lowest waste mass allowed for the VEMP Airborne drums (i.e. 50 kg).

Using the equation above allows calculation of the high TRU activity range for each transuranium isotope as illustrated in Table V-1.

**Table V-1.**  
**Low- and High-Activity Ranges, and Final Waste Form Activities**  
**Associated with TRU Isotopes for VEMP Airborne Waste**

Isotope	Low TRU Activity Range (nCi/g)	High TRU Activity Range (nCi/g)	Final Waste Form Activity (nCi/g)
Plutonium-238	6.3E-05	4.39	1.2E-02
Plutonium-239	1.7E-05	1.14	3.2E-03
Plutonium-240	1.1E-05	0.79	2.2E-03
Plutonium-242	9.2E-07	0.06	1.8E-04
Neptunium-237	2.8E-07	0.02	5.4E-05
Americium-241	6.0E-04	39.73	1.1E-01
Americium-243	4.8E-05	3.29	9.4E-03
Curium-245	4.5E-04	30.78	8.6E-02
Curium-246	7.3E-05	5.01	1.4E-02
<b>Total</b>	<b>1.3E-03</b>	<b>85.21</b>	<b>2.4E-01</b>

## 6.0 Enriched Uranium Data

Although the uranium isotopes associated with this waste stream would be present in quantities that would not require them to be reported, it appears that these wastes may contain enriched uranium. Using the data provided in Table IV-1, the data input for activity is based on dividing the high-activity range by  $3.7 \text{ E}+10 \text{ Bq/Ci}$  to reflect the appropriate curie concentrations on a cubic meter basis. Table VI-1 was created as input for the enrichment calculation:

**Table VI-1.**  
**Data Input for the Uranium Enrichment Calculation**

Isotopes	High-Activity Range (Ci/m <sup>3</sup> )	Specific Activity (Ci/g) <sup>1</sup>
Uranium-232	2.7E-03	2.2E+01
Uranium-233	6.5E-05	9.8E-03
Uranium-234	2.2E-5	6.3E-03
Uranium-235	2.2E-6	2.2E-06
Uranium-236	5.1E-6	6.5E-05
Uranium-238	1.6E-5	3.4E-07

- Specific activities for each isotope were calculated based on the standard activity for radium-226. Since this isotope has a known specific activity of 1 Ci/g, the specific activity of any isotope can be calculated as follows:

$$SA_{\text{Iso}} = \left[ \frac{1,600 \text{ yr}}{T^{1/2}_{\text{Iso}}} \times \frac{226}{AM_{\text{Iso}}} \right] (\text{Ci/g}) \quad \text{Eq. 7}$$

Where:

- $SA_{\text{Iso}}$  = Specific activity of isotope in question (Ci/g)
- 1,600 = Half life of radium-226 (years)
- 226 = Atomic mass of radium-226
- $T^{1/2}_{\text{Iso}}$  = Half life of isotope in question (years)
- $AM_{\text{Iso}}$  = Atomic mass of isotope in question

Using the data in Table VI-1, the uranium mass can be calculated for each isotope by dividing the high-activity range value by the specific activity. This results in uranium gram values per cubic meter of waste:

U-232 =	1.2E-04 grams per m <sup>3</sup> of waste
U-233 =	6.6E-03 grams per m <sup>3</sup> of waste
U-234 =	3.5E-03 grams per m <sup>3</sup> of waste
U-235 =	1.0E+00 grams per m <sup>3</sup> of waste
U-236 =	7.8E-02 grams per m <sup>3</sup> of waste
U-238 =	4.7E+01 grams per m <sup>3</sup> of waste.

Based on the above gram values, the uranium-235 enrichment for VEMP airborne wastes can be calculated as:

$$U-235_{Enr} = \left[ \frac{U-235_{Mass}(g)}{Total\ U_{Mass}(g)} \right] \times 100 \quad \text{Eq. 8}$$

In this case, an enrichment of 2.0 percent U-235 by mass has been determined.

Based on the uranium mass information above, a maximum U-235 gram value can be estimated based on the type of package used. VEMP airborne wastes will be packaged in 55-gallon drums (0.208 m<sup>3</sup>) and steel boxes (about 2.5 m<sup>3</sup>). Since the maximum mass concentration of uranium-235 is estimated to be about 1 gram/m<sup>3</sup>, the highest U-235 gram loading could equate to about 2.5 grams per container. It should be noted, however, that this value could never be reached since the maximum mass concentration above is based on a drum calculation. As discussed in Section 3.2, the maximum waste mass density for boxes is only 60% of that compared to drums (i.e., 3,338 lbs/m<sup>3</sup> for boxes vs. 5,528 lbs/m<sup>3</sup> for drums). Therefore, in reality, the maximum U-235 mass loading would only equate to about 1.5 grams per container.

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