SAFETY ANALYSIS AND INVENTORY CONTROL OF TRANSURANIC AND LOW-LEVEL WASTE IN COMMON STORAGE

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ABSTRACT

This paper describes a methodology developed for the inventory control of low-level waste (LLW) and transuranic (TRU) waste, when both are stored in the same location, and both contribute to an inventory constrained by safety considerations.

Development of the method arose from the necessity to make safety analysis calculations for the addition of LLW, in quantities greater than existing inventory limits would allow when stored with TRU waste, in the Hanford Central Waste Complex (CWC).

Ensuring that the dose consequences of credible releases are maintained at low-hazard limits or less, was used to allow greater than Type A quantities of LLW into the CWC. Basically, what happens is the original limited amount of TRU allowed is reduced by some equivalent amount of LLW introduced. The total quantity of TRU, and LLW in excess of Type A quantities, must be administratively maintained via curie equivalency factors to ensure operation as a low-hazard facility. The "equivalency" between TRU and LLW proposed here is specific only to the CWC, but the methodology can be used for other specific applications, such as TRU and LLW storage or handling facilities where inventory limits must be enforced or where a simplified inventory system is required.

INTRODUCTION

This paper describes a methodology developed at the Hanford Site for the inventory control of low-level waste (LLW) and transuranic (TRU) waste, when both are stored in the same location, and both contribute to an inventory constrained by safety considerations.

This method can be applicable to safety evaluations for TRU and LLW storage or handling facilities where inventory limits must be enforced or where a simplified inventory system is required.

DEVELOPMENT HISTORY

Development of the method arose from the necessity to make safety analysis calculations for the addition of LLW, in quantities greater than existing inventory limits would allow when stored with TRU waste, in the Hanford Central Waste Complex (CWC).

In accordance with U.S. Department of Energy (DOE) Orders 5820.2A, *Radioactive Waste Management* and 5400.3, *Hazardous and Radioactive Mixed Waste Program*, TRU solid waste is placed in interim storage at the Hanford Site pending eventual shipment to the Waste Isolation Pilot Plant (WIPP) (1,2). All TRU waste meeting the definition of radioactive mixed waste (RMW) must be stored in the CWC, a *Resource Conservation and Recovery Act of 1976* (RCRA), and *Toxic Substances Control Act of 1976* (TSCA) approved storage facility (3,4). Most solid LLW is disposed of at the Hanford Site 200 Areas disposal facilities. All LLW that is also RMW, must also be stored in the CWC.

The CWC is a multi-facility complex, located in the 200 West Area of the Hanford Site, that receives and stores the solid RMWs generated at the Hanford Site. The solid wastes handled at the CWC include contact-handled TRU, LLW, RMW, and TRU/polychlorinated biphenyl wastes.

Compliance with a low-hazard classification criteria, as established in the WHC-CM-4-46, *Nonreactor Facility Safety Analysis Manual*, (low-hazard allows for a minimization of design requirements) for the CWC is ensured by establishing facility inventory limits for the materials stored at the CWC (5). These inventory limits are calculated to ensure that the dose consequences of the worst-case credible releases are always less than the low-hazard dose limits. Specifically, a 169.8 Plutonium Equivalent Curie (PE-Ci) TRU waste total (6.28 E + 12 Bq ^{239}Pu) for any building unit in combination with a limitation on truck inventories was established to ensure that the dose to the maximally exposed onsite individual is less than 5.0 rem (5.0 E-02 Sv) effective dose equivalent. Note that the unit of PE-Ci is a unit that encompasses the activities of all of the isotopes of plutonium, and while not a unit of the International System of Units (SI), it is a common usage term for both Hanford and WIPP, and is used in the waste acceptance criteria for WIPP (6). The methodology that was developed at Hanford for the inventory control of LLW and TRU waste was closely associated with PE-Ci quantities of TRU material. As a consequence, this unit will be used throughout. Further, the dose consequence limits of potential releases at Hanford are specified in units of rems and these will be utilized in developing the methodology also.

The CWC operation was at the same time based on LLW limits in accordance with Title 49, *Code of Federal Regulations*, Part 173 (40 CFR 173) for low specific activity (LSA) through Type A quantities, (*i.e.*, the non-TRU waste packages received and stored in the CWC were limited to LSA or Type A quantities) (7). When limited to these quantities, contributions to the dose consequences were very small. Thus, TRU contaminated waste was the major factor in calculated accident consequences and in determining CWC inventory.

Recent chemical analyses of Hanford waste tank core samples generated RMW with curie quantities greater than Type A waste. To accommodate the greater than Type A quantities, the safety analysis for the CWC was revised and the inventory control was modified without impact to the existing safety envelope. This was accomplished using the same concept of ensuring that the consequences of credible releases are always less than the allowed dose limits.

METHODOLOGY FOR THE HANFORD CENTRAL WASTE COMPLEX

The calculations provided in the next section establish the inventory limits for the CWC before the need to store greater than Type A waste was imposed. These limits ensure that the facility remains within the low-hazard category. The low hazard limits (WHC-CM-4-46) ensure that the dose to the maximally exposed onsite individual, an individual located 300 meters south of the CWC, is ≤5.0 rem Effective Dose Equivalent (EDE) (50 rem limiting organ) and that the dose to the maximally exposed offsite individual, an individual located 12.2 km west of the CWC, is ≤0.5 rem EDE (5.0 rem limiting organ) or ≤0.5 rem EDE for the ingestion pathway for a winter release (5).

Central Waste Complex Inventory Limits

The principle of operation for the CWC is that the facility review and authorization level (hazard classification) for the CWC is always "low" based on restricted radioactive material inventories in the buildings and administrative controls over transported containers. In essence, the radioactive (predominantly TRU waste, until this new methodology was applied) inventories in each building or shipment are restricted such that the credible involvement of an entire building or shipment will not exceed the dose consequence limits for a low-hazard facility. The limits, which ensure that the low-hazard classification would not be exceeded, were derived conservatively by relating the low hazards for onsite and offsite dose consequences to the product of the source times the release fraction value.

In determining dose consequences from an accident, the inventory at risk is multiplied by the release fraction due to the accident (fire, explosion, etc) to determine the amount released (source term). For any accident scenario, the source term is then multiplied by the appropriate radiological unit release term to determine the onsite or offsite radiological consequences.

$$\text{Inventory (PE-Ci)} \times \text{Release Fraction} \times \text{Radiological Unit Release (rem/PE-Ci)} = \text{Dose (rem)} \qquad \text{(Eq.1)}$$

For the respirable release fraction that might be achieved as a result of a fire, NUREG-1320 is utilized (8). Considering the nature of the contained materials (paper, plastic, metals, rubber, etc., with surface and or internal contamination) and the packaging, a release fraction of 5.3 E-04 is given for the burning of contaminated combustible solids where the contaminant is a powder.

The GENII code, which is an atmospheric dispersion model, was used to determine the radiological unit release calculations (9). GENII is capable of calculating doses from both acute and chronic releases, including options for annual dose, committed dose, and accumulated dose. GENII evaluates the following exposure pathways; direct exposure via water, soil, and air as well as inhalation and ingestion pathways.

GENII calculations show that 0.09 PE-Ci of respirable ^{239}Pu released at ground level at the CWC, results in a limiting onsite dose of 5.0 rem EDE (the low-hazard limit for onsite individuals).

If the above relationship (Eq.1) for dose is rearranged to determine a maximum inventory based on the limiting onsite dose:

$$\frac{Dose}{Release\ Fraction \times Unit\ Release} = \text{Limiting Inventory} \qquad \text{(Eq. 2)}$$

Then it would require (0.09 PE-Ci)/ (5.3×10^{-4}) = 169.8 PE-Ci be involved before the onsite low-hazard criteria of 5.0 rem EDE is challenged.

$$\frac{\text{GENII limiting onsite } \textit{dose consequence}}{\textit{release fraction} \text{ for burning of contaminated waste}} = \frac{0.09\ PE-Ci}{5.3\ E-4} = 169.81 \text{ PE-Ci} \qquad \text{(Eq. 3)}$$

In addition to onsite calculations, offsite and winter ingestion calculations were made in a similar manner. These calculations confirmed that the limiting hazard classification criteria is 5.0 rem EDE onsite for ^{239}Pu.

Therefore, a 169.8 PE-Ci total for any of the individual CWC building units in combination with a limitation on truck inventories is established to ensure that the dose to the maximally exposed onsite individual receives less than 5.0 rem EDE.

Inventory Control Methods for Storage of Transuranic and Low-Level Waste

This same concept of ensuring that all dose consequences are maintained below the low hazard classification criteria was extended to allow greater than Type A quantities of LLW into the CWC. Basically, what happens is the original amount of TRU allowed is partially replaced by some equivalent amount of LLW introduced. The total quantity of TRU, and LLW in excess of Type A quantities, must be administratively maintained via a curie equivalency factor to ensure operation as a low hazard facility. In order for the building limits to comprise isotopes of both TRU waste, and LLW in excess of Type A quantities, the Central Waste Complex Dose Equivalent Curie (CWC DE-Ci) unit is employed. The CWC DE-Ci is a unit of curie equivalency between transuranic and non-transuranic materials specific to the CWC. The CWC DE-Ci is calculated using the parameters for the worst-case accident scenario (truck crash into a storage building with fire release) and the parameters for the individual isotopes. These factors are obtained from GENII analysis and are shown in Table I for a representative sample of isotopes that may be stored within the CWC. The fourth column of Table I with units of "CWC DE-Ci/Ci" shows the equivalency factors for the CWC. A CWC DE-Ci is equal in value to one PE-Ci; however, the CWC DE-Ci concept is employed to ensure that the equivalency factors remain CWC specific. Calculation of the CWC DE-Ci, for material containing both TRU and non-TRU, is presented in the following paragraphs.

The factors were determined using unit releases determined by the GENII code with plume meander taken into account. The results of the unit releases were ratioed with each of the three hazard classification limits (onsite, offsite, and environmental impact). For each isotope the maximum of

TABLE I
Representative Equivalency Factors for Calculating CWC Container Contributions to Onsite Limits

Nuclide	Maximum Limit Ratio (1/Ci)	Nuclide Release Fraction	Equivalency Factor CWC DE-Ci/Ci
H-3	6.5 E-06	1.0 E+00	1.1 E-03
KR-85	1.3 E-07	1.0 E+00	2.2 E-05
SR-90	4.8 E-02	5.3 E-04	4.3 E-03
I-129	6.0 E-02	1.0 E+00	1.0 E+01
CS-137	1.1 E-03	5.3 E-04	9.9 E-05
PU-238	1.0 E+01	5.3 E-04	9.0 E-01
PU-239	1.1 E+01	5.3 E-04	1.0 E+00
PU-240	1.1 E+01	5.3 E-04	1.0 E+00
PU-241	1.8 E-01	5.3 E-04	1.6 E-02
AM-241	2.8 E+01	5.3 E-04	2.5 E+00
PU-242	1.0 E+01	5.3 E-04	9.0 E-01

the three ratio limits represents which hazard classification criteria is most limiting. The maximum limit ratio for a particular isotope may be thought of as the fraction of the low hazard classification criteria reached per curie of that isotope released in an accident. Thus, if one Ci of an isotope were released in an accident, the maximum limit ratio is the fraction of the limiting low hazard classification criteria that would be attained in that accident. As an example of how limit ratios are calculated, the ^{90}Sr unit releases from the GENII analysis are divided by the low hazard classification criteria and shown below. The quantities calculated are the limit ratios for ^{90}Sr.

Onsite EDE:

$$Limit\ ratio = \frac{(3.5\,E-02\,rem\ EDE/Ci)}{(5.0\,rem\ EDE)} \quad \text{(Eq. 4)}$$

$$= 7.0\text{ E-03 Ci}^{-1}$$

Onsite maximum organ:

$$Limit\ ratio = \frac{(4.25\,E-01\,rem/Ci)}{(50.0\,rem)} \quad \text{(Eq. 5)}$$

$$= 8.5\text{ E-03 Ci}^{-1}$$

Site boundary winter ingestion:

$$Limit\ ratio = \frac{(2.4\,E-02\,rem\ EDE/Ci)}{(0.5\,rem\ EDE)} \quad \text{(Eq. 6)}$$

$$= 4.8\text{ E-02 Ci}^{-1}$$

The maximum limit ratio for ^{90}Sr is 4.8 E-02 Ci^{-1} from the site boundary winter ingestion criteria. Thus, for ^{90}Sr the winter ingestion criteria is limiting and is used as the basis to determine its equivalency factor. The maximum limit ratios for the isotopes in the table are contained in the second column of Table I.

The maximum limit ratio multiplied by a separate release fraction (which is by definition curies of isotope in inventory) puts the maximum limit ratio in terms of total inventory as opposed to release amount. The release fraction must be appropriate for both the scenario and the isotope under analysis. Since the scenario forming the basis for the calculations is a fire, the release fraction of 5.3 E-04 is used here. However, in the case of isotopes that are or could be gases or volatile solids during the accident a release fraction of 1.0 is assumed. These release fractions are contained in the third column of the Table I.

$$Limit\ ratio = 4.8\,E-02\,Ci^{-1} \times 5.3\,E-04 \quad \text{(Eq. 7)}$$

(in terms of total inventory)

$$= 2.54\text{ E-05 Ci}^{-1}$$

The final equivalency factor is calculated by multiplying the facility inventory limit of 169.8 PE-Ci (CWC DE-Ci) by the maximum limit ratio (in terms of total inventory). Multiplication by the inventory limit previously calculated converts the maximum limit ratio from a fraction to the equivalent number of CWC DE-Ci per Ci of the isotope. Thus, the final equivalency factor is in units of CWC DE-Ci per Ci of isotope.

$$Final = 169.8\,PE-Ci \times 2.54\,E-04\,Ci^{-1} \quad \text{(Eq. 8)}$$

Equivalency
Factor

$$= 4.3\,E-03\,\frac{CWC\ DE-Ci}{Ci}$$

In practice, the equivalency factors can be multiplied by the amount of each isotope (in curie or PE-Ci) to obtain the equivalent number of CWC DE-Ci. The sum of all the CWC DE-Ci calculated for a particular shipment, building, etc., is then compared to the appropriate inventory limits established for the CWC.

As an example of how this methodology would be used, the contents of one 17H drum with 200 Ci of ^{90}Sr, 2000 Ci of ^{137}Cs and 30 PE-Ci of TRU is converted to an equivalent amount of CWC DE-Ci.

$$200\,Ci\ ^{90}Sr \times 4.3\,E-03\,\frac{CWC\ DE-Ci}{Ci\ ^{90}Sr} \quad \text{(Eq. 9)}$$

$$= \quad 0.86\ CWC\ DE-Ci$$

$$2000\,Ci\ ^{137}Cs \times 9.9\,E-05\,\frac{CWC\ DE-Ci}{Ci\ ^{137}Cs} \quad \text{(Eq. 10)}$$

$$= \quad 0.20\ CWC\ DE-Ci$$

$$30\,PE-Ci \times 1.0\,E{+}00\,\frac{CWC\,DE-Ci}{PE-Ci} \qquad \text{(Eq. 11)}$$

= 30.0 CWC DE-Ci

Total 31.06 CWC DE-Ci

EXTENDED APPLICATIONS

This method can be applied to many facilities which store both TRU and LLW. Instead of having to provide separate inventory limits for each isotope present, the isotopes can be put on an equivalent level via this equivalency factor method. The CWC DE-Ci factors as mentioned, are specific to the CWC because of the release fractions, the particular meteorological conditions, distances to the receptors, and the applicable limiting dose consequence criteria. Another facility may use this method by inserting the specific values that are unique to their facility.

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