REGULATORY CONSIDERATIONS OF WASTE EMPLACEMENT WITHIN THE WIPP REPOSITORY: RANDOM VERSUS NON-RANDOM DISTRIBUTION

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ABSTRACT

The U.S. Department of Energy (DOE) is responsible for disposing of transuranic waste in the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico. As part of that responsibility, DOE must comply with the U.S. Environmental Protection Agency's (EPA) radiation protection standards in Title 40 Code of Federal Regulations (CFR), Parts 191 and 194. This paper addresses compliance with the criteria of 40 CFR Section 194.24(d) and 194.24(f) that require DOE to either provide a waste loading scheme for the WIPP repository or to assume random emplacement in the mandated performance and compliance assessments.

The DOE established a position on waste loading schemes during the process of obtaining the EPA's initial Certification in 1998. The justification for utilizing a random waste emplacement distribution within the WIPP repository was provided to the EPA. During the EPA rulemaking process for the initial certification, the EPA questioned DOE on whether waste would be loaded randomly as modeled in long-term performance assessment (PA) and the impact, if any, of non-random loading. In response, DOE conducted an impact assessment for non-random waste loading. The results of this assessment supported the contention that it does not matter whether random or non-random waste loading is assumed for the PA.

The EPA determined that a waste loading plan was unnecessary because DOE had assumed random waste loading and evaluated the potential consequences of non-random loading for a very high activity waste stream. In other words, the EPA determined that DOE was not required to provide a waste loading scheme because compliance is not affected by the actual distribution of waste containers in the WIPP.(1)

As a measure of assurance for future recertifications, all transuranic (TRU) waste is tracked as it is emplaced in the WIPP repository. Information on TRU waste components, including the quantities of 10 individual radionuclides that are important to performance, are inventoried for each drum and maintained within a comprehensive tracking system known as the WIPP Waste Information System. This information on the as-received inventory, along with revised inventory projections from the TRU waste generator sites, will be included in the performance

assessments for future recertifications. Based on current understanding of the emplaced waste and the projected waste, the assumption of random emplacement is expected to remain valid for the operational life of WIPP.

INTRODUCTION

Within the initial Compliance Certification Application (CCA), DOE elected to assume that waste would be emplaced in the WIPP in a random fashion (2). In accordance with the requirements of Title 40 CFR §194.24(d), a waste loading scheme is only required when random emplacement is not utilized in the performance and compliance assessments. Since DOE incorporated the assumption of random waste loading into its performance and compliance assessments (pursuant to §§194.32 and 194.54, respectively), a waste loading plan was not necessary. The EPA concurred with this result as part of the terms and conditions of the WIPP Certification (1):

> The EPA determined that, because the DOE had assumed random waste loading, a final waste loading plan was unnecessary. The EPA determined that, in the PA, DOE accurately modeled random emplacement of waste in the disposal system. Since EPA concurred with DOE that a final waste loading plan was unnecessary, DOE does not have to further comply with §194.24(f), requiring DOE to conform with the waste loading conditions, if any, used in the PA and compliance assessment. Therefore, EPA finds that DOE complies with §§194.24(d) and (f).

DISCUSSION

Releases calculated by PA models include solid releases due to cuttings/cavings and spallings, and dissolved releases due to direct brine release and solute transport in the Culebra dolomite above the Salado Formation. The cuttings/cavings, spallings, and direct brine releases are rapid processes that occur at the time of a borehole intrusion; release from the Culebra is a long-term process based on solute transport in groundwater. Results presented within the CCA demonstrated that the solid releases dominate (>99%) the total releases. This paper therefore focuses on the methodology for representing random emplacement in the solid release calculations and the potential impacts from non-random emplacement on solid releases.

Both solid release mechanisms are directly related to processes that occur when a drill bit first penetrates a repository. The methodology for calculating these drilling intrusions is as follows. First, it was assumed that the location of each borehole intrusion within the waste disposal region is sampled randomly in space and that each penetration could encounter either contact-handled transuranic waste (CH-TRU) or remote-handled transuranic (RH-TRU) waste. This was achieved in the PA by separating a plan view of the WIPP footprint into 144 regions, as shown in Figure 1, and requiring each borehole intrusion to penetrate a single region.

Each of the 144 regions contains both excavated and unexcavated areas at the repository horizon. Within the repository footprint (Figure 1), a borehole has approximately a 20 percent chance of entering an excavated region and approximately an 80 percent chance of passing through the pillars in an unexcavated region. Boreholes that penetrate excavations may penetrate CH-TRU waste, RH-TRU waste, or panel closures that contain no waste. RH TRU waste is actually emplaced in the walls of the repository, rather than in the excavated regions in Figure 1. However, for simplicity, PA assumes that a borehole that penetrates an excavated area has approximately a 12% chance of encountering RH-TRU waste and an 88% chance of encountering CH-TRU waste. These percentages correspond to the relative plan-view areas of each waste type (2) [*p. 6-184*].

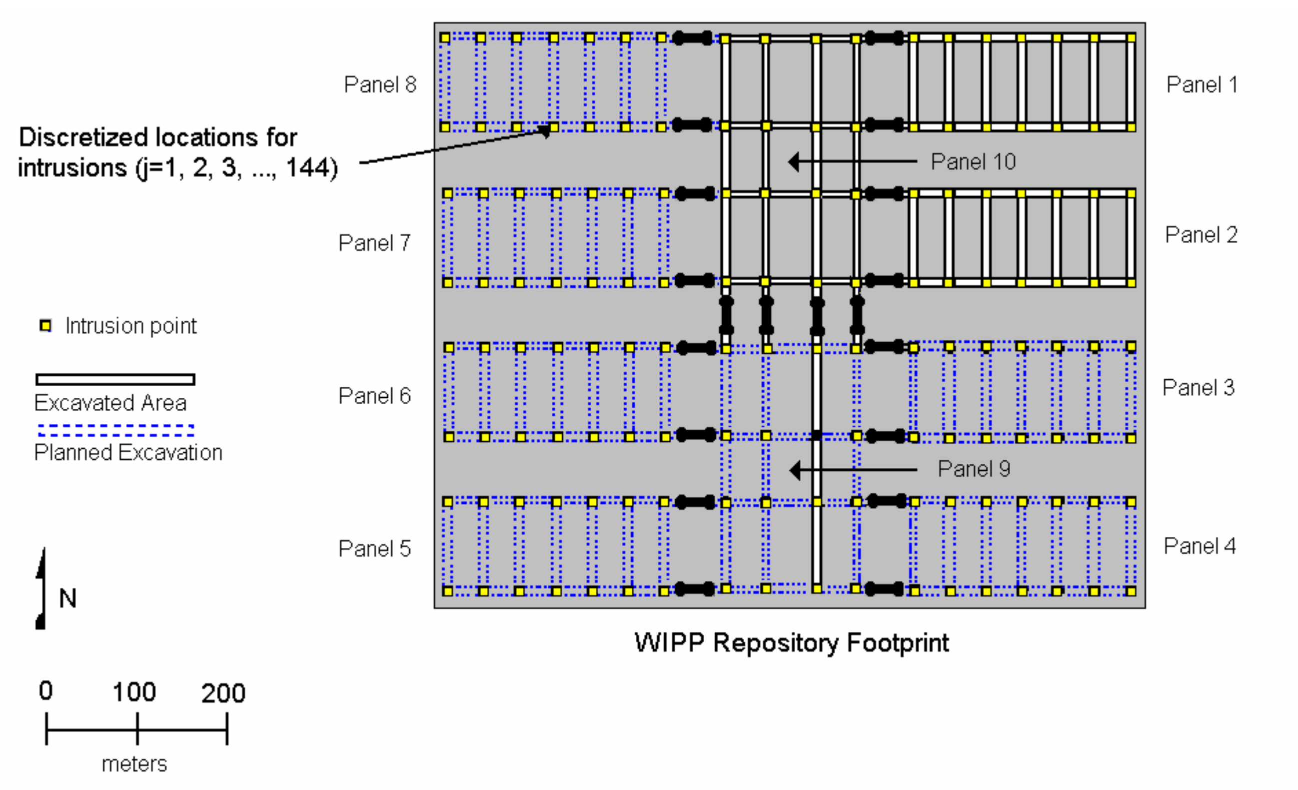

Figure 1. WIPP repository footprint with 144 regionalized borehole intrusion

The activity of radionuclides may vary by many orders of magnitude among waste containers (2) [*App. BIR*]. DOE characterized this variability by compiling information about the characteristics of 569 CH-TRU waste streams and approximately 401 RH-TRU waste streams for the CCA. Because the RH-TRU waste is only 1.5 percent of the total EPA units of CH-TRU waste, all the RH-TRU waste streams were grouped together into a single, average RH-TRU waste stream. The EPA unit is a measure of the normalized activity of all radionuclides, referenced to the initial Curies of transuranic radionuclides with half-life greater than 20 years that are initially present in the repository.

The mechanism of cuttings/cavings is based on a drill bit intersecting and removing relatively small portions of the waste. More specifically, cuttings refers to waste material that is directly removed when a drill bit passes through the repository and is then transported to the surface in the circulating drilling mud. Cavings refers to waste material that is scoured from the surface of the borehole by the circulating drilling mud and subsequently transported to the surface. The radioactivity released by cuttings/cavings may be sensitive to variability in the volume, activity, and location of individual waste streams.

The calculation of cuttings/cavings release directly incorporates the assumption of random emplacement of the 569 CH TRU waste streams into the computational methodology. The methodology to determining the activity associated with a borehole intrusion into CH TRU waste is as follows:

1. A drill bit is assumed to penetrate three waste containers because 55-gallon drums of CH TRU waste are stacked three-high in the repository.
2. Each of the three containers penetrated by the drill bit can come from a different waste stream, having different levels of radioactivity at the time of the intrusion.
3. A distribution of waste stream activity, weighted by the waste stream volumes, is randomly sampled three times and averaged to determine the mean CH TRU activity released by the intrusion. PA actually has 9 waste stream distributions that correspond to 100 years, 125 years, 175 years, 350 years, 1,000 years, 3,000 years, 5,000 years, 7,500 years, and 10,000 years after repository closure. These distributions provide the capability to interpolate for the waste stream activity at the time of the intrusion.

If random sampling determined that the borehole penetrates RH-TRU waste, 100 % of the material removed is assumed to be from the single RH TRU waste stream. Again, the activity of this waste stream is defined at 9 points in time to provide the ability to interpolate activity to the time of intrusion.

The calculation of spallings release from a direct borehole intrusion into the repository is also based on the assumption of random emplacement of CH TRU waste streams. The spallings process is based on the transport of solid waste particulates in high velocity gas flows that could occur when a drill bit penetrates a high pressure repository. The volume removed by the spallings process[a], 0.5 to 4.0 m^3, is between 2 and 19 times the internal volume of a 55-gallon drum (0.208 m^3). In this situation, the spallings process has the potential to release waste from many drums and waste streams. Assuming that CH TRU waste streams are emplaced randomly throughout the repository, the activity released by spallings can be accurately approximated by the average activity of all CH TRU waste streams at the time of the intrusion. In other words, use of an average activity for all CH TRU waste streams is justified because the average spall volume (2.25 m^3) is equal to approximately 11 drums (55-gallon, or 0.208 m^3) and the mean activity for 11 randomly sampled waste streams will be closely approximated by the average activity in the repository.

Spallings releases conservatively assume that an intrusion always encounters CH TRU waste. This is a reasonable assumption because the spallings process, which is based on entrainment and transport of particulates in rapidly flowing gas, probably cannot occur for RH TRU waste that is emplaced in individual boreholes in the walls of the repository.

[a] The spallings volume is an uncompacted volume of waste corresponding to the initial conditions in the repository. The uncompacted volume is a total initial volume that includes the volume of the waste itself and the non-waste volumes that may have be filled with backfill or may be empty porosity, such as within a 55-gallon drum.

In response to comments made by EPA when assessing the information in the CCA, DOE submitted additional analyses to address the possible impact of non-random loading on cuttings/cavings and spallings releases. The potential impact from nonrandom loading was estimated by considering an extreme case whose release is conditional on:

1. The occurrence of a single intrusion 100 years after decommissioning into the highest-activity waste stream containing at least 810 drums.
2. The association of a maximum-volume spalling or cuttings and cavings events under a borehole intrusion scenario (4)

Of the waste streams in the CCA inventory, the residue material generated by Rocky Flats was the highest activity waste stream that contained more than 810 drums. The Rocky Flats residue represents 20,100 drum equivalents of waste (4,182 m^3 out of a total of 168,500 m^3 CH TRU) (2), with 0.0496 EPA units per drum equivalent at 100 years. This activity corresponds to

$$\frac{0.0496\, EPA\ Units\ per\ Drum}{0.208\, m^3\ per\ Drum} = 0.238\, EPA Units / m^3\ of\ waste\ at\, 100\ years.$$

Since the ratio of waste volume to disposal-region volume is (168,500 m^3)/(436,000 m^3) = 0.386, it follows that the Rocky Flats residue material has (0.238)*(0.386) = 0.092 EPA units per cubic meter of uncompacted waste. The volume of uncompacted waste includes the waste itself, any backfill that may be present, and the void volume in the repository (2) [*App. SA, p. SA-9*]. This last step is necessary because the waste volume released by spallings is based on uncompacted volume.

Based on an average activity of 0.092 EPA units per cubic meter, the maximum spallings release of 4 m^3 of Rocky Flats' residue from an intrusion at 100 years would result in the release of 0.368 EPA units. Over the 10,000 year period modeled in PA approximately 95% of all futures involve fewer than 10 drilling intrusions into the repository. The probability that three out of ten intrusions would intersect the region containing the Rocky Flats residue is 0.00157 (binomial distribution). The total release from three "worst case" intrusions is then:

$$\left(\frac{4\, m^3}{Intrusion}\right)\left(\frac{0.092\, EPA Units}{m^3}\right)\left(3\, Intrusions\right) = 1.1\, EPA\ Units.$$

This release is almost an order of magnitude below the release limit of 10 EPA Units at a probability of 0.001, as specified in §191.13(a) (3).

This analysis shows that even in a worse case scenario, when the highest activity waste stream that contained more than 810 drums is emplaced in one contiguous location rather than randomly, releases are well within the allowable limits. This finding provides support for the DOE decision to assume random emplacement for performance assessment.

As a result of the CCA and this impact analysis, DOE concluded that the CCDF is not affected by sampling uncertainty and that the assumption of random emplacements of containers in the

WIPP is not important to the position of the CCDF. Therefore, a load management plan is unnecessary to support performance assessment assumptions (1) [*p. 4-35*]. Releases of the highest activity waste streams loaded non-randomly into a single disposal region could result in a shift in the compliance measure at very low probability levels, but an analysis of the "worst case" showed that estimated release is below the regulatory limit by almost an order of magnitude.

CURRENT INFORMATION

Based on the information gathered since March 1999, when the WIPP repository received its first TRU waste shipment, all waste parameters remain within the maximum inventory values for the performance assessment for the CCA. Most importantly, the amount and distribution of the major radionuclides (those determined to contribute greater than 95% of the total decayed activity, as calculated at the anticipated year of closure in 2033) was within an acceptable loading configuration utilized for an individual waste panel. Displayed in Table I are the radionuclides of interest and the total activity of each emplaced in Panel 1 of the WIPP repository (6).

Panel 1 is approximately 10% of the repository footprint area. When compared to a uniform distribution of individual radionuclides, Panel 1 contains greater activity of certain isotopes, such as Am241 and Pu239, than an average panel would contain, assuming the waste was distributed homogeneously throughout the repository. Likewise, other isotopes such as U233, Cs137 and Sr90, are at a minimal concentration in Panel 1. However, if the total inventory coming to WIPP remains consistent with the inventory estimate for the CCA, the isotope activity in other panels will balance the risk of releases from Panel 1. For example, the increased risk of release of Am241 from Panel 1 will be balanced with a decreased risk of release of AM241 from other areas of the repository, assuming that borehole intrusions occur randomly throughout the repository footprint.

Table I. Radionulcides attributed to 99% of the total WIPP waste activity

Radionuclide	Total Projected Radionuclide Activity at Closure (Curies) (1)	Activity of Emplaced Waste in Panel 1 (Curies) (6)	Percent of Total Projected Radionuclide Activity in Panel 1
Am241	4.48E+05	1.17E+05	26.0%
Pu238	2.61E+06	6.03E+03	0.2%
Pu239	7.95E+05	1.36E+05	17.1%
Pu240	2.15E+05	3.06E+04	14.2%
Pu242	1.17E+03	3.07E+00	0.3%
U233	1.95E+03	2.45E-01	0.0%
U234	5.08E+02	1.29E+00	0.3%
U238	5.01E+01	6.13E+00	12.2%
Sr90	2.16E+05	0.00E+00	0.0%
Cs137	2.24E+05	3.22E-04	0.0%

CONCLUSION

Based on the emplaced waste information, gathered from early 1999 through September 2002, the original assumptions used to support the long-term performance assessment, as presented in the original compliance certification application for the WIPP, still remain valid.

The collection of data and information during the operational life of WIPP adds a measure of assurance, in terms of continuously updating the understanding of long-term repository behavior. For assurance of regulatory compliance, TRU waste is tracked as it is emplaced in the WIPP repository. The information on the individual waste components of regulatory importance (including quantities of individual radionuclides) are inventoried for each drum or shipment, and maintained within a comprehensive tracking system known as the WIPP Waste Information System. In the 2003 and future recertification applications, the received waste inventory information, along with revised projections of inventory estimates from TRU waste generators, will be evaluated for potential impacts on the assumption of random emplacement of waste within the performance assessment process. Based on the most recent data and information on emplaced TRU waste, the assumption of random emplacement, as originally stated in the CCA, will remain valid for the 2003 recertification, and is expected to remain valid for the operational life of WIPP.

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