Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant

Appendix WCL

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Waste Component Limits

CONTENTS

TABLES

ACRONYMS

CFR	Code of Federal Regulations
CH	contact handled
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
LWA	Land Withdrawal Act
TRU	transuranic
TWBIR	Transuranic Waste Baseline Inventory Report
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant

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APPENDIX WCL

40 CFR § 194.24(c) states that the U.S. Department of Energy (DOE) shall specify the limiting values for waste components to be emplaced in the repository:

> "For each waste component identified and assessed pursuant to paragraph (b) of this section, the Department shall specify the limiting value (expressed as an upper or lower limit of mass, volume, curies, concentration, etc.), and the associated uncertainty (i.e., margin of error) for each limiting value, of the total inventory of such waste proposed for disposal in the disposal system . . . . "

Appendix WCA identifies the specific waste components that are associated with the waste proposed for disposal at the Waste Isolation Pilot Plant (WIPP) that address paragraph (b) of 40 CFR § 194.24. Tables WCA-2 and WCA-12 present waste characteristics and the associated components expected prior to the analysis to have significant effect on the performance of the disposal system. Tables WCA-3 and WCA-13 present waste characteristics and associated components expected prior to the analysis to have negligible or insignificant effect on the performance of the disposal system. Table WCA-4 presents waste characteristics and components that were considered but not included in the performance assessment.

This appendix presents the rationale for establishing limits (or for not establishing limits, as the case may be) for those waste components identified as potentially significant in Table WCA-2. As well, it presents the rationale for not establishing limits for one component, organic ligands, that was not anticipated to have significant impact on the results of the assessment. Because the sensitivity analysis (Appendix SA) shows that disposal system performance is not sensitive to most properties of the emplaced waste, limits need not be established for other components listed in Table WCA-3.

Table WCL-1 shows the components listed as potentially significant in Tables WCA-2 and WCA-13, the organic ligands component from Table WCA-3, and the waste characteristics these components influence, the constituents of the component for which assaying during emplacement is required, and the limits for emplacement of each component. Following this table are discussions of the rationale for the proposed assaying and emplacement limits for each component. All of the components listed in Tables WCA-3, WCA-4, and WCA-13 were found to be insignificant to disposal system performance. Therefore, it is not necessary to establish emplacement limits for them other than the relatively coarse limits based on the Transuranic Waste Baseline Inventory Report (TWBIR) (DOE 1996) or imposed through the specific criteria imposed on waste through limitations in the Waste Acceptance Criteria (WAC).

Table WCL-1. Emplacement Limits for Waste Components

Components	Associated Characteristics	Constituent Components Requiring Assaying	Emplacement Limits
radionuclides	*radioactivity at closure* radioactivity after closure solubility colloid formation redox state	^{241}Am ^{238}Pu ^{239}Pu ^{240}Pu ^{242}Pu ^{233}U ^{234}U ^{238}U ^{90}Sr ^{137}Cs	*none*[a]
ferrous metals (iron)	redox potential H_2 gas generation complexing with organic ligands	none	minimum = 2×10^7 kg (amount from containers)[b]
cellulose,	gas generation humic colloids (see below)	sum	maximum = 2×10^7 kg[c]
plastics, rubber	gas generation		
sulfates	gas generation	none	none[d]
nitrates	gas generation	none	none[d]
solid components	particle size effective shear resistance to erosion tensile strength	none	none
free water emplaced *with waste*	gas generation	none	maximum = 1685 m^3 *(limit of 1% total* waste volume as set by the WAC)[e]
humic substances	radionuclide-bearing humic colloids	none	none
nonferrous metals (metals other than iron)	bind with organic ligands and prevent increased solubility	none	minimum = 2×10^3 kg[f]
organic ligands	*solubility*	*none*	*none*[d]

[a] Inventory curie content will be tracked.
[b] Minimum sets to ensure sufficient reactants for reducing radionuclides to lower and less soluble oxidation states. Average density for contact-handled transuranic (CH-TRU) container steel of 139 kilograms per cubic meter multiplied by the design basis value of 168,500 cubic meters.
[c] Maximum set to ensure sufficient MgO backfill is available to react with CO_2 produced. See SWCF-A:WBS.1.1.09.1.1(BC):QA, also in WPO#36453.
[d] For the current waste generation processes that are documented in the TWBIR
[e] *1 percent of the design basis values for CH-TRU of 168,500 cubic meters*
[f] Minimum quantity for complexing with organic ligands (see Appendix SOTERM, Section SOTERM.5).

WCL.1 Radionuclide Components

As discussed in Appendix WCA, nine component radionuclides have activities greater than one EPA unit at closure: ^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{233}U, ^{234}U, ^{90}Sr, and ^{137}Cs. The total activity of the waste at emplacement and during the entire 10,000-year performance period is dominated by the activities of four emplaced radionuclides: ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{240}Pu. The radionuclides, ^{242}Pu, ^{233}U and ^{234}U, have significantly less total activity than the other Am and Pu components, but since their activities exceed one EPA unit they are not excluded from assaying. The ^{238}U component is to be assayed as well, because its large mass fraction and low activity dilutes the overall activity of transported uranium species. ^{90}Sr and ^{137}Cs can contribute to direct releases at the surface resulting from inadvertent intrusion in the first several hundred years or so after closure. Because of radioactive decay and ingrowth, the major contributors to the overall activity of the repository among these radionuclides change during 10,000 years. For the first several hundred years, ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{240}Pu are important contributors to the total activity of the waste. At the present and projected inventory level, ^{90}Sr and ^{137}Cs may be important for about 200 years. ^{241}Am is important for about 3,000 years. At 10,000 years, ^{239}Pu and ^{240}Pu remain as the only significant contributers to the total activity of the waste. Because the activities of these ten radionuclides in existing and projected waste overwhelmingly exceed the activities of all other radionuclides combined, they are the only radionuclides that need to be limited (see Appendix WCA).

The total activity of the waste is not important for 40 CFR § 194.24(c), because the containment requirements are normalized to the initial inventory. However, the performance assessment is sensitive to relative changes in inventory curie content as a function of radionuclide decay and ingrowth over time. The magnitude of change in the total curie content depends on the initial ratios of the total activities of the assayed radionuclides at the time of repository closure. Accordingly, the results of the performance assessment analysis are conditional on the ratios assumed, which can be derived from data presented in Appendix WCA. 40 CFR § 194.15(a)(5) states that

> "In submitting documentation of continued compliance pursuant to section 8(f) of the WIPP LWA, . . . Updated documentation shall include: . . . A description of all waste emplaced in the disposal system since the most recent compliance certification or re-certification application."

As appropriate, the performance assessment to be conducted for compliance recertification purposes will use adjusted inventory curie content reflecting any significant changes relative to projected values for the four important radioisotopes. The effect of replacing the original estimated ratios with estimates obtained in the future will be captured in recertification performance assessment results. Therefore, the inventory curie content for only the nine important radioisotopes plus ^{238}U need to be tracked. At repository closure, the ratios of the activities of the ten listed radionuclides may or may not be similar to those ratios used in this assessment, but compliance with the containment requirements of 40 CFR § 191.13 will be maintained for the full capacity of emplaced waste at the WIPP.

WCL.2 Ferrous and Ferrous-Alloy Components

Ferrous and ferrous-alloy metal components in the waste have two significant effects on the repository. Ferrous and ferrous-alloy metals may corrode, thus creating gas (see Section 6.4.3.3), and they provide reducing conditions in the repository (see Sections 6.4.3.4, 6.4.3.5, and Appendices WCA, Section WCA.4, and SOTERM, Section SOTERM.4). These effects are captured in performance assessment as described in Chapter 6.0 (Section 6.4.3.3).

The results of this performance assessment show that release of radionuclides is sensitive to the quantity of gas generated. There are two release mechanisms, direct brine release and spallings, that occur only if the pressure in the repository exceeds 8 megapascals (for example, Appendix MASS, Stoelzel and O'Brien, Attachment 16-2, and Appendix SA, Figures SA-8 and SA-17). Eight megapascals corresponds to the hydrostatic pressure at the repository depth in a column of drilling mud. If repository pressure is sufficient for these two direct release mechanisms to occur, the quantity of radionuclides released is controlled by factors other than the total pressure in the repository.

The waste inventory contains sufficient ferrous and ferrous-alloy components that gas could be generated significantly in excess of that required to reach 8 megapascals in the repository. The predicted long-term performance of the repository is improved if insufficient gas is generated to produce pressures of 8 megapascals, because direct brine release and spallings mechanisms do not occur at lower pressures. The actual quantity of gas generated is not solely a function of the emplaced waste, but depends as well on the quantity of brine that flows into the repository and is available to corrode the metal. Since low gas generation (resulting in pressures less than 8 megapascals) is controlled by processes not related to waste components (for example, brine inflow), and because performance assessment results are not sensitive to gas generation in excess of that required to produce a repository pressure of 8 megapascals, it is unnecessary to place restrictions on the quantity of ferrous and ferrous-alloy metals emplaced for the purpose of controlling the quantity of gas generated.

Ferrous and ferrous-alloy metals (and their corroded products) provide the reactants that reduce radionuclides to lower and less-soluble oxidation states. As discussed in Appendix WCA, the anticipated quantity of these metals to be emplaced in the WIPP is two to three orders of magnitude in excess of the quantity required to assure reducing conditions. The waste containers supply more than enough iron to provide adequate reductant. Therefore, no upper or lower limit need be established for the quantity of ferrous and ferrous-alloy metals that may be emplaced, beyond the present projection of containers.

WCL.3 Cellulose, Plastic, Rubber, Nitrate, and Sulfate Components

The cellulose, plastic, rubber, nitrate, and sulfate components of the waste influence the production of CH_4 gas in the repository by microbial action. Performance assessment assumes that the process of microbial degradation is viable only 50 percent of the time. Therefore, a lower limit for these materials is effectively zero. As discussed in the preceding section, releases are not sensitive to the quantity of gas generated, and the inventory of ferrous and ferrous-alloy metals is already in excess of that required to produce a significant amount of gas, which is that amount required to produce pressures of 8 megapascals, or greater. Therefore, the additional influence of components influencing microbial degradation are negligible, and it is unnecessary with respect to gas generation to assign an upper limit on the amount of cellulosics that may be emplaced in the repository, with one caveat. One of the barriers incorporated into the design of the WIPP facility as an assurance requirement is MgO backfill (Chapter 7.0, Section 7.4.3). The amount of MgO backfill currently projected for the WIPP is in excess of the amount needed to react with the CO_2 produced (Appendix SOTERM, Section SOTERM.2.2). A coarse upper limit is set on the sum of cellulosics, plastics, and rubbers to ensure that the amount of MgO emplaced is adequate.

WCL.4 Solid Components

Solid components in the waste affect the waste characteristics of effective shear resistance to erosion, particle size, and tensile strength. These properties affect the cavings and spallings releases. The basic assumption for the assignment of these properties is that fully degraded waste will have the least favorable properties, and will eventually be similar to granular materials whose properties can be measured today. The actual properties of the waste over the 10,000-year regulatory period are unknown, since the physical nature of the degraded waste is unknown. The parameter values assigned are chosen to conservatively reflect measured properties of natural and constructed materials. These properties are reasonable analogs for degraded waste. The effective shear resistance to erosion (see Appendix PAR) used to calculate cavings is based on the erodibility of unconsolidated marine clays and other easily eroded materials, and is considered to be near a physical limit for the minimum value of this property. The minimum particle size (see Appendix PAR) used in the range for the spallings model is based on assuming an average pore diameter consistent with an average waste permeability; this value is considered conservative because in reality the waste will not have a uniform distribution of permeability (see Appendix SA, Section SA.3). The larger particles will define the more permeable pathways, along which most gas will flow during a spalling event, and larger particles are less likely to spall than small particles. Last, the strength of the waste assigned for the spalling process is fixed at 1 pound per square inch, which is considerably less than the measured strength of granular materials that were assumed to have properties analogous to those of degraded waste (Berglund et al. 1996).

The properties assumed for solid components in performance assessment bound the least favorable behavior of these components. Therefore, the performance assessment analysis is not conditional on the quantities and kinds of solid components that will be emplaced.

WCL.5 Water Component

The water component in the waste is the subject of other regulations. The amount of water emplaced with the waste can affect the rate at which gas is generated for a short period soon after closure, but the small quantity of water acceptable in the waste is not of concern for long-term performance. Consequently, there is no need to monitor water in the waste for compliance with 40 CFR § 194.24(c). In fact, the quantity of water in the waste used for performance assessment calculations is greater than the Waste Acceptance Criteria allow, so the only limit on free water content of the waste is set by the Waste Acceptance Criteria.

WCL.6 Humic Substances Component

Humic substances are likely to be introduced into the repository as a component of wastes containing soils or may form in situ from reactions involving microbial metabolites produced during degradation of cellulosics. Humic substances will dissolve until a solubility limit is reached. Dissolved humic substances are colloidal in nature and may complex radionuclides. The radionuclide-bearing humic colloids may be transported in moving liquid and contribute to a radionuclide release.

In performance assessment, a steady-state concentration of humic colloids is assumed to exist in the repository during the performance period. This concentration is not inventory limited; in other words, it is assumed in performance assessment that sufficient source materials exist that a constant concentration of humic colloids will be present at all times. Because it is assumed that there is sufficient solid material present for a steady-state concentration to exist at all times in the repository, performance assessment results are not conditional on the quantity of total humic substances present, and there is effectively no limit to the quantity of humic substances that may be emplaced in the repository. If few humic substances are present, then the concentration of humic colloids will be less than that assumed in performance assessment, with negligible or beneficial consequences to the overall analysis. Therefore, no minimum limit is necessary for the quantity of humic substances to be emplaced in the WIPP.

WCL.7 Nonferrous Metals Component

The nonferrous metals present in the waste stream impact performance assessment because they will dissolve and bind to organic ligands, thereby reducing the impact of organic ligands on the solubility of radionuclides. According to the existing and projected inventory and composition of waste canister steels, these components will be emplaced in considerable excess of that required to sequester organic ligands. Assay is therefore not required for these metals (see Appendix SOTERM, Section SOTERM.5). Calculations for low-ionic strength NaCl solution showed that the available Ni alone can complex 99.8 percent of available EDTA, rendering it unavailable for complexation with actinides.

WCL.8 Organic Ligands Component

The effects of organic ligands were eliminated from this performance assessment because the presence of large quantities of magnesium from the MgO backfill (see Appendix SOTERM, Section SOTERM.6) effectively sequesters organic ligands in the repository and thereby prevents them from influencing the concentration of dissolved actinides. The actual inventory of organic ligands is difficult to quantify, and if considerably more organic ligands are contained in emplaced waste than presently estimated (refer to TWBIR, Appendices B3 and B4), actinide solubilities could be affected. Increased amounts of organic ligands in the waste stream would have an insignificant effect on performance of the WIPP disposal system because of the more likely preferential binding of organic ligands with magnesium and other nonferrous metals, which will render them ineffective in increasing radionuclide solubilities. The quantity of organic ligands in existing and future waste is extremely small, so the use of organic ligands in processes that generate waste will be monitored. If the rate of use of organic ligands in waste-generating processes increases significantly over current usage, the DOE will take action to control the quantity of organic ligands emplaced in the repository.

WCL.9 Summary of Activities to Satisfy Criteria in 40 CFR § 194.24(c)

As shown in the preceding discussion, the only activity that is necessary to satisfy the requirements of 40 CFR § 194.24(c)(4) and (5) is tracking changes in future projections of total inventory curie content. The purpose of tracking is to assure that the ratio of emplaced activities of the ten waste component radionuclides recommended for assay is either similar to that assumed in this performance assessment or reflected in performance assessments used for re-certification. Coarse lower limits are set on ferrous and non-ferrous metals. These limits are based on current estimates (see TWBIR, Tables 3-2 and 3-4, and Appendix SOTERM, for quantity of nonferrous metals used). A coarse upper limit is set on the sum of cellulose, plastics, and rubbers to ensure that the amount of MgO emplaced is adequate. The only other limits that need to be imposed are those set by the Waste Acceptance Criteria. This conclusion was reached after (1) consideration of the components in the waste, which are discussed in Appendix WCA, (2) analysis of the results of the performance assessment, which are discussed in Section 6.5 and Appendix SA, and (3) consideration of the assumptions made regarding waste component availability and their physical properties for the performance assessment, which are discussed in Section 6.4 and supporting appendices.

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