560065

Sandia National Laboratories
Waste Isolation Pilot Plant

Analysis Package for EPA Unit Loading Calculations for the 2014 Compliance Recertification Application Performance Assessment (CRA-2014 PA)

Revision 0

Authors:	Dwayne C. Kicker	[signature]	5/8/2013
	Print	Signature	Date
	Todd Zeitler	[signature]	5/8/2013
	Print	Signature	Date
Technical Review:	Janis Trone	[signature]	5/8/2013
	Print	Signature	Date
QA Review:	Shelly R. Nielsen	[signature]	5-8-13
	Print	Signature	Date
Management Review:	Sean Dunagan	[signature]	5/8/2013
	Print	Signature	Date

TABLE OF CONTENTS

TABLES

FIGURES

1. INTRODUCTION

The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, has been developed by the U.S. Department of Energy (DOE) for the geologic (deep underground) disposal of transuranic (TRU) waste. Containment of TRU waste at the WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the regulations set forth in Title 40 of the Code of Federal Regulations (CFR), Part 191. The DOE demonstrates compliance with the containment requirements according to the Certification Criteria in Title 40 CFR Part 194 by means of performance assessment (PA) calculations performed by Sandia National Laboratories (SNL). WIPP PA calculations estimate the probability and consequence of potential radionuclide releases from the repository to the accessible environment for a regulatory period of 10,000 years after facility closure. The models used in PA are maintained and updated with new information as part of an ongoing process. Improved information regarding important WIPP features, events, and processes typically results in refinements and modifications to PA models and the parameters used in them. Planned changes to the repository and/or the components therein also result in updates to WIPP PA models. WIPP PA models are used to support the repository recertification process that occurs at five-year intervals following the receipt of the first waste shipment at the site in 1999.

PA calculations were included in the 1996 Compliance Certification Application (CCA) (U.S. DOE 1996), and in a subsequent Performance Assessment Verification Test (PAVT) (MacKinnon and Freeze 1997a, 1997b and 1997c). Based in part on the CCA and PAVT PA calculations, the EPA certified that the WIPP met the regulatory containment criteria. The facility was approved for disposal of TRU waste in May 1998 (U.S. EPA 1998). PA calculations were an integral part of the 2004 Compliance Recertification Application (CRA-2004) (U.S. DOE 2004). During their review of the CRA-2004, the EPA requested an additional PA calculation, referred to as the CRA-2004 Performance Assessment Baseline Calculation (PABC) (Leigh et al. 2005), be conducted with modified assumptions and parameter values (Cotsworth 2005). Following review of the CRA-2004 and the CRA-2004 PABC, the EPA recertified the WIPP in March 2006 (U.S. EPA 2006).

PA calculations were completed for the second WIPP recertification and documented in the 2009 Compliance Recertification Application (CRA-2009). The CRA-2009 PA resulted from continued review of the CRA-2004 PABC, including a number of technical changes and corrections, as well as updates to parameters and improvements to the PA computer codes (Clayton et al. 2008). To incorporate additional information which was received after the CRA-2009 PA was completed, but before the submittal of the CRA-2009, the EPA has requested an additional PA calculation, referred to as the 2009 Compliance Recertification Application Performance Assessment Baseline Calculation (PABC-2009) (Clayton et al. 2010), be undertaken which included updated information (Cotsworth 2009). Following the completion and submission of the PABC-2009, the WIPP was recertified in 2010 (U.S. EPA 2010).

The Land Withdrawal Act (U.S. Congress 1992) requires that the DOE apply for WIPP recertification every five years following the initial 1999 waste shipment. The 2014 Compliance Recertification Application (CRA-2014) is the third WIPP recertification application submitted by the DOE for EPA approval. The PA executed by SNL in support of the CRA-2014 is detailed in AP-164 (Camphouse 2013). The CRA-2014 PA includes a number of technical changes and parameter refinements, as well as a redesigned WIPP panel closure system. Results found in the CRA-2014 PA are compared to those obtained in the PABC-2009 in order to assess repository performance in terms of the current regulatory baseline.

This report documents the computational method to determine the WIPP repository radionuclide inventory information for use in the cuttings/cavings calculation for the CRA-2014. Furthermore, this report provides the results from the implementation of that method and compares them with the results from the PABC-2009 PA. This work was done in accordance with AP-164 and supports the WIPP PA code CCDFGF (Camphouse 2013, Section 2.3.2.1).

2. PROBLEM DESCRIPTION

Environmental radiation protection standards for management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes as defined in 40 CFR 191 require human intrusion scenarios to be included in the PA calculations for repositories. Five distinct human intrusion scenarios that impact release from the repository are defined for the WIPP PA. Four of these involve a single drilling intrusion that occurs at various times after repository closure. Two types of drilling intrusions are considered: 1) a borehole is drilled through a single waste panel and intersects a pressurized brine pocket located approximately 250 meters below the repository, and 2) a borehole is drilled into the repository, but does not intersect a brine pocket. One multiple intrusion scenario is considered.

For scenarios that involve a drilling intrusion into the repository, release mechanisms include cuttings, cavings and spallings. To calculate the extent of release from these mechanisms, an estimate of the radionuclide content, expressed as the EPA Unit of the waste encountered via drilling is required.

Determination of the radionuclide content of the waste encountered via drilling is problematic because it is uncertain. The radionuclide content of waste streams disposed in the WIPP repository is uncertain, as is the loading of those waste streams. The EPA has offered guidance about how to handle this uncertainty, stating that in the absence of a waste loading plan for the repository, random waste emplacement should be assumed (see 40 CFR 194.24). Therefore, following EPA guidance, it is assumed that waste is emplaced randomly in the repository and the probability of encountering any given waste stream in a drilling intrusion is directly proportional to the volume of that waste stream in the repository.

3. COMPUTATIONAL METHOD

For the WIPP PA, information about the radionuclides that would be encountered during drilling is quantified using the metric of EPA Units. The activity in EPA Units for a radionuclide is the initial source term activity (in Curies (Ci)) of that radionuclide divided by the product of the "waste unit factor" and the release limit (in Ci/unit of waste) for the same radionuclide (Sanchez et al. 1997).

The activity of an isotope in EPA Units is calculated using the following equation:

$$E_i = \frac{w_i}{f_w \cdot r_i} \tag{1}$$

where E_i is the radionuclide activity expressed in EPA Units for radionuclide i,
r_i is the release limit from 40 CFR 191 for radionuclide i,
f_w is the waste unit factor, and
w_i is the waste-stream-scale activity in curies (Ci) for radionuclide i.

For the TRU waste to be disposed of in the WIPP, the unit of waste (also called "waste unit factor") is "An amount of transuranic wastes containing one million curies of alpha-emitting transuranic radionuclides with half-lives greater than 20 years" (40 CFR 191, Appendix A, Table 1). Release limits in Ci are specified in Appendix A of 40 CFR 191. Release limits and the number of Ci in an EPA Unit vary by radionuclide. For example, the release limit for ^{239}Pu is 100 Ci per unit of waste. Therefore, if the unit of waste is 2.06, one EPA Unit is 206 Ci of the isotope. However, for an isotope with a release limit of 1000 Ci per unit of waste (e.g., ^{135}Cs), one EPA unit is 2060 Ci of the isotope.

For the WIPP PA, the activity in EPA Units at each time interval of interest of each of the major radionuclides (i.e., those for which 40 CFR 191 specifies release limits) in each waste stream is calculated. Then, the activity of the entire waste stream (at the time interval) in EPA Units is calculated as:

$$E_{ws} = \sum E_i \tag{2}$$

where E_{ws} is the radionuclide activity of a waste stream expressed in EPA Units,
E_i is the radionuclide activity expressed in EPA Units for radionuclide i.

Once the activity of each waste stream in the metric of EPA Units is determined at each time interval, the probability of encountering each stream during a drilling intrusion is calculated as:

$$p_{ws} = \frac{v_{ws}}{V} \tag{3}$$

where p_{ws} is the probability of encountering a waste stream during a drilling intrusion,
v_{ws} is the volume of an individual waste stream, and
V is the total volume of waste in the repository.

The radionuclides that are important for modeling the direct solid release pathway (via the CCDFGF code) for the CRA-2014 are: ^{241}Am, ^{244}Cm, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{90}Sr, ^{233}U, and ^{234}U (Kicker and Zeitler 2013, Section 3.2 and Table 5). Kicker and Zeitler (2013) indicated that these 10 radionuclides accounted for 99.55% of the EPA units at the time of repository closure in the CRA-2014 inventory. All ten radionuclides are modeled in EPAUNI, Version 1.15A, which is the computational code that generates the data described above for use in calculating potential cuttings/cavings releases from the repository.

EPAUNI input files were developed by Kicker and Zeitler (2013, Appendix D) and include *EPU_CRA14_CH.INP*, *EPU_CRA14_CH_MISC.INP*, *EPU_CRA14_RH.INP*, and *EPU_CRA14_RH_MISC.INP*. Input files can be found in the CMS library LIBCRA14_EPU. All inputs are fetched at run time by the scripts, and outputs and run logs are automatically stored by the scripts. Results of the code's waste activity calculations can be found in the CMS library LIBCRA14_EPU. Command language scripts, referred to here as EVAL run scripts, are used to implement and document the running of all software codes. These scripts, which are the basis for the WIPP PA run control system, are stored in the LIBCRA14_EVAL CMS library.

4. RESULTS

Section 4.1 discusses the output of EPAUNI in terms of total volume. Section 4.2 discusses EPA Units and their relationship over time. Section 4.3 discusses the contributing isotopes.

4.1 TOTAL VOLUME

The volumes shown in Table 4-1 are provided to illustrate which waste streams are the primary contributors to total waste inventory volume. Table 4-1 indicates that 35 separate waste streams contribute more than 70% of the total volume of the inventory to be disposed in the WIPP. Of these 35 waste streams, ten contribute more than 40% of the volume. CH waste stream RLPFP-01 provides 7.46% of the total volume while CH waste stream WP-BN510 provides about 5.48% of the inventory to be disposed at WIPP. The top RH waste stream, RL105-09, contributes 1.30% of the total volume and ranks 18th. The total volume for the CRA-2014 inventory, 175,570 m^3 (Table 4-1), is similar to the total volume of the inventory used for the PABC-2009 PA, 175,500 m^3 (Fox and Clayton 2010, Table 4-1). Information regarding total volumes for all 528 waste streams can be found in the files *EPU_CRA14BL_CH.OUT* and *EPU_CRA14BL_RH.OUT* in the CMS library LIBCRA14_EPU. Waste stream volume is the same for all time periods provided in these output files. (Note: "BL" in filenames refers to the CRA-2014 "baseline" calculation; however, the same EPAUNI input and output files are used in all cases specified in AP-164 (Camphouse 2013).)

4.2 EPA UNITS

The total EPA Unit values in Table 4-2 were provided to illustrate which waste streams are the primary contributors to the total EPA Units over the entire population of waste inventory at closure. The table identifies 35 waste streams that offer the greatest contribution at closure as output by the code EPAUNI. Table 4-2 indicates that 35 separate waste streams contribute more than 80% of the total EPA Units at closure in the waste inventory. Of these 35 waste streams, 13 contribute more than 60% of the total EPA Units at closure in the waste inventory. The top two CH waste streams, SR-W026-WSB-2 and LA-MHD01.001, provide 9.59% and 8.14%, respectively, of the total EPA Units at closure in the waste inventory. The top RH stream, RL300-08, contributes 1.04 % of the total EPA Units at closure and ranks 19th.

The total EPA Units in the waste inventory for the CRA-2014, 10,197 EPA Units (Table 4-2), is slightly higher than the total EPA Units in the waste inventory used for the PABC-2009 PA, 10,080 EPA Units (Fox and Clayton 2010, Table 4-2). All 528 waste streams and their total

EPA Units can be found in the files *EPU_ CRA14BL_CH.DIA* and *EPU_ CRA14BL_RH.DIA* in the CMS library LIBCRA14_EPU.

Table 4-1. WIPP CH- and RH-TRU Waste Streams by Total Volume

Rank Order	Waste Stream ID	Stream Type	Volume [m³]	% of Total	Cumulative %
1	RLPFP-01	CH	1.31E+04	7.46%	7.46%
2	WP-BN510	CH	9.63E+03	5.48%	12.95%
3	LA-MHD01.001	CH	9.01E+03	5.13%	18.08%
4	SR-W026-MFFF-1	CH	7.89E+03	4.49%	22.57%
5	IN-ID-RF-S5300	CH	6.69E+03	3.81%	26.38%
6	IN-BNINW216	CH	6.15E+03	3.50%	29.89%
7	RL200-02	CH	5.89E+03	3.35%	33.24%
8	WP-ID-SDA-SLUD	CH	5.42E+03	3.09%	36.33%
9	WP-BNINW216	CH	5.37E+03	3.06%	39.39%
10	IN-BN510.1	CH	4.77E+03	2.72%	42.10%
11	WP-RF029.01	CH	4.32E+03	2.46%	44.56%
12	WP-LA-MHD01.00	CH	3.71E+03	2.11%	46.68%
13	IN-ID-RF-S3114	CH	3.55E+03	2.02%	48.70%
14	WP-SR-W027-221	CH	3.39E+03	1.93%	50.63%
15	WP-SR-W027-FB-	CH	3.07E+03	1.75%	52.38%
16	WP-ID-RF-S5300	CH	2.78E+03	1.58%	53.96%
17	IN-ID-SDA-Slud	CH	2.43E+03	1.38%	55.35%
18	RL105-09	RH	2.29E+03	1.30%	56.65%
19	WP-SR-W027-221	CH	2.23E+03	1.27%	57.92%
20	WP-RLMPDT.001	CH	2.13E+03	1.21%	59.13%
21	WP-BN836	CH	1.76E+03	1.00%	60.14%
22	WP-SR-W026-772	CH	1.66E+03	0.95%	61.08%
23	LA-MHD04.001	CH	1.58E+03	0.90%	61.98%
24	SR-W026-WSB-2	CH	1.57E+03	0.89%	62.88%
25	RL231Z-01	CH	1.54E+03	0.88%	63.75%
26	WP-RF002.01	CH	1.46E+03	0.83%	64.58%
27	WP-RF118.01	CH	1.45E+03	0.83%	65.41%
28	WP-BN510.1	CH	1.41E+03	0.80%	66.21%
29	WP-RF009.01	CH	1.34E+03	0.76%	66.98%
30	WP-ID-RF-S3114	CH	1.27E+03	0.72%	67.70%
31	WP-INW216.001	CH	1.26E+03	0.72%	68.42%
32	RL325-01	CH	1.21E+03	0.69%	69.11%
33	WP-INW218.001	CH	1.12E+03	0.64%	69.74%
34	LL-M001	CH	1.10E+03	0.63%	70.37%
35	SR-W027-HBL-Bo	CH	1.08E+03	0.62%	70.99%
*	*	*	*	*	*
*	*	*	*	*	*
528	AW-5410N	RH	1.13E-01	0.00%	100.00%
	Total:		175,570	100.00%	

NOTE: From EPAUNI output files, *EPU_CRA14BL_CH.OUT* and *EPU_CRA14BL_RH.OUT*.

Table 4-2. WIPP CH- and RH-TRU Waste Streams by Total EPA Units; Time 0 (Calendar Year 2033)

Rank Order	Waste Stream ID	Stream Type	EPA Units	% of Total	Cumulative %
1	SR-W026-WSB-2	CH	9.78E+02	9.59%	9.59%
2	LA-MHD01.001	CH	8.30E+02	8.14%	17.73%
3	WP-RF009.01	CH	6.63E+02	6.50%	24.23%
4	RLPFP-01	CH	6.49E+02	6.37%	30.60%
5	WP-SR-W027-221	CH	5.98E+02	5.87%	36.47%
6	WP-LA-MHD01.00	CH	5.49E+02	5.38%	41.85%
7	WP-RF118.01	CH	5.10E+02	5.00%	46.85%
8	WP-SR-MD-PAD1	CH	2.92E+02	2.87%	49.71%
9	WP-INW216.001	CH	2.86E+02	2.80%	52.51%
10	LA-CIN01.001	CH	2.79E+02	2.73%	55.25%
11	WP-SR-W027-235	CH	2.72E+02	2.67%	57.92%
12	RL308-01	CH	2.06E+02	2.02%	59.94%
13	WP-BNINW216	CH	1.90E+02	1.86%	61.80%
14	LA-TA-21-12	CH	1.63E+02	1.60%	63.40%
15	SR-W026-MFFF-1	CH	1.58E+02	1.55%	64.95%
16	IN-BNINW216	CH	1.29E+02	1.27%	66.22%
17	WP-BN510	CH	1.20E+02	1.17%	67.39%
18	WP-RLHMOX.001	CH	1.12E+02	1.10%	68.49%
19	RL300-08	RH	1.06E+02	1.04%	69.53%
20	WP-LA-OS-00-01	CH	1.03E+02	1.01%	70.54%
21	AW-T031.1322	RH	9.80E+01	0.96%	71.50%
22	WP-RF003.01	CH	9.30E+01	0.91%	72.41%
23	WP-RLMPDT.001	CH	9.09E+01	0.89%	73.30%
24	WP-SR-LA-PAD1	CH	8.56E+01	0.84%	74.14%
25	KN-B234TRU	CH	7.95E+01	0.78%	74.92%
26	RL200-02	CH	7.67E+01	0.75%	75.67%
27	RLPURX-01	CH	7.41E+01	0.73%	76.40%
28	WP-RF006.01	CH	6.87E+01	0.67%	77.07%
29	WP-RF032.01	CH	6.56E+01	0.64%	77.72%
30	WP-BN304	CH	6.12E+01	0.60%	78.32%
31	LL-M001	CH	6.04E+01	0.59%	78.91%
32	WP-RF128.01	CH	5.92E+01	0.58%	79.49%
33	WP-RF029.01	CH	5.66E+01	0.56%	80.05%
34	LA-TA-21-06	CH	5.61E+01	0.55%	80.60%
35	WP-RF005.01	CH	5.55E+01	0.54%	81.14%
*	*	*	*	*	*
*	*	*	*	*	*
528	SA-W138M	CH	1.91E-08	0.00%	100.00%
	Total:		10,197	100.00%	

NOTE: From EPAUNI output files, *EPU_CRA14BL_CH.DIA* and *EPU_CRA14BL_RH.DIA*.

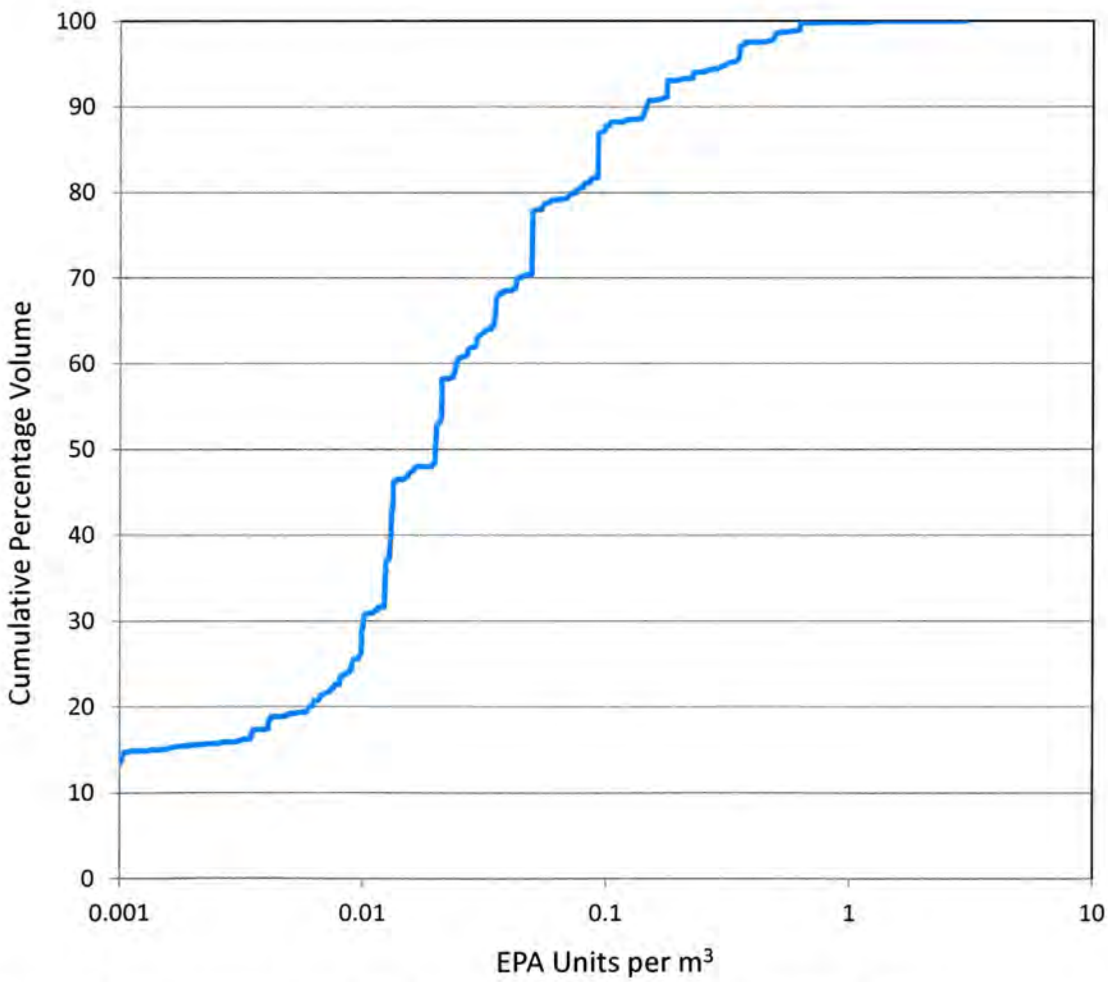
Table 4-3 shows the total EPA Unit values at 10,000 years after closure for the top 35 waste streams. The total EPA Units at 10,000 years has significantly decreased to 2,388 EPA Units compared to 10,197 EPA Units at closure. The total EPA Units at 10,000 years has increased since the PABC-2009 from 1,680 to 2,388 EPA Units. The top CH waste stream, RLPFP-01, provides 11.62% of the total EPA Units in the waste inventory at 10,000 years, where at closure, it provided 6.37%. The top RH waste stream, AW-T031.1322, contributes only 0.55% of the total EPA Units in the waste inventory at 10,000 years after closure and ranks 32nd.

Table 4-3. WIPP CH- and RH-TRU Waste Streams by Total EPA Units; Time 10,000 (Calendar Year 12033)

Rank Order	Waste Stream ID	Stream Type	EPA Units	% of Total	Cumulative %
1	RLPFP-01	CH	2.77E+02	11.62%	11.62%
2	WP-RF118.01	CH	2.72E+02	11.41%	23.03%
3	WP-RF009.01	CH	2.23E+02	9.33%	32.36%
4	LA-MHD01.001	CH	1.89E+02	7.93%	40.29%
5	WP-LA-MHD01.00	CH	1.27E+02	5.31%	45.60%
6	SR-W026-MFFF-1	CH	9.02E+01	3.78%	49.38%
7	WP-BN510	CH	5.45E+01	2.28%	51.66%
8	LA-CIN01.001	CH	5.40E+01	2.26%	53.92%
9	WP-RF003.01	CH	5.14E+01	2.15%	56.08%
10	RL308-01	CH	4.47E+01	1.87%	57.95%
11	RL200-02	CH	4.00E+01	1.67%	59.62%
12	WP-RLMPDT.001	CH	3.81E+01	1.59%	61.22%
13	KN-B234TRU	CH	3.77E+01	1.58%	62.80%
14	WP-RF006.01	CH	3.73E+01	1.56%	64.36%
15	WP-RLHMOX.001	CH	3.48E+01	1.46%	65.81%
16	WP-RF032.01	CH	3.47E+01	1.45%	67.27%
17	WP-RF128.01	CH	3.44E+01	1.44%	68.71%
18	WP-RF141.02	CH	3.00E+01	1.26%	69.96%
19	RLPURX-01	CH	3.00E+01	1.25%	71.22%
20	WP-RF029.01	CH	2.77E+01	1.16%	72.38%
21	WP-RF010.01	CH	2.52E+01	1.06%	73.44%
22	WP-RF005.01	CH	1.95E+01	0.82%	74.25%
23	WP-SR-W027-FB-	CH	1.89E+01	0.79%	75.04%
24	RL216Z-02	CH	1.82E+01	0.76%	75.80%
25	WP-RF002.01	CH	1.78E+01	0.74%	76.55%
26	LL-M001	CH	1.70E+01	0.71%	77.26%
27	RL209E-01	CH	1.63E+01	0.68%	77.94%
28	WP-RLRFETS.001	CH	1.49E+01	0.63%	78.57%
29	WP-INW211.001	CH	1.46E+01	0.61%	79.18%
30	WP-RF008.01	CH	1.39E+01	0.58%	79.76%
31	WP-RF001.01	CH	1.35E+01	0.57%	80.33%
32	AW-T031.1322	RH	1.32E+01	0.55%	80.88%
33	WP-INW216.001	CH	1.31E+01	0.55%	81.43%
34	WP-BN510.1	CH	1.29E+01	0.54%	81.97%
35	WP-RF005.02	CH	1.18E+01	0.50%	82.47%
*	*	*	*	*	*
*	*	*	*	*	*
528	SA-W138M	CH	2.15E-15	0.00%	100.00%
	Total:		2,388	100.00%	

NOTE: From EPAUNI output files, *EPU_CRA14BL_CH.DIA* and *EPU_CRA14BL_RH.DIA*.

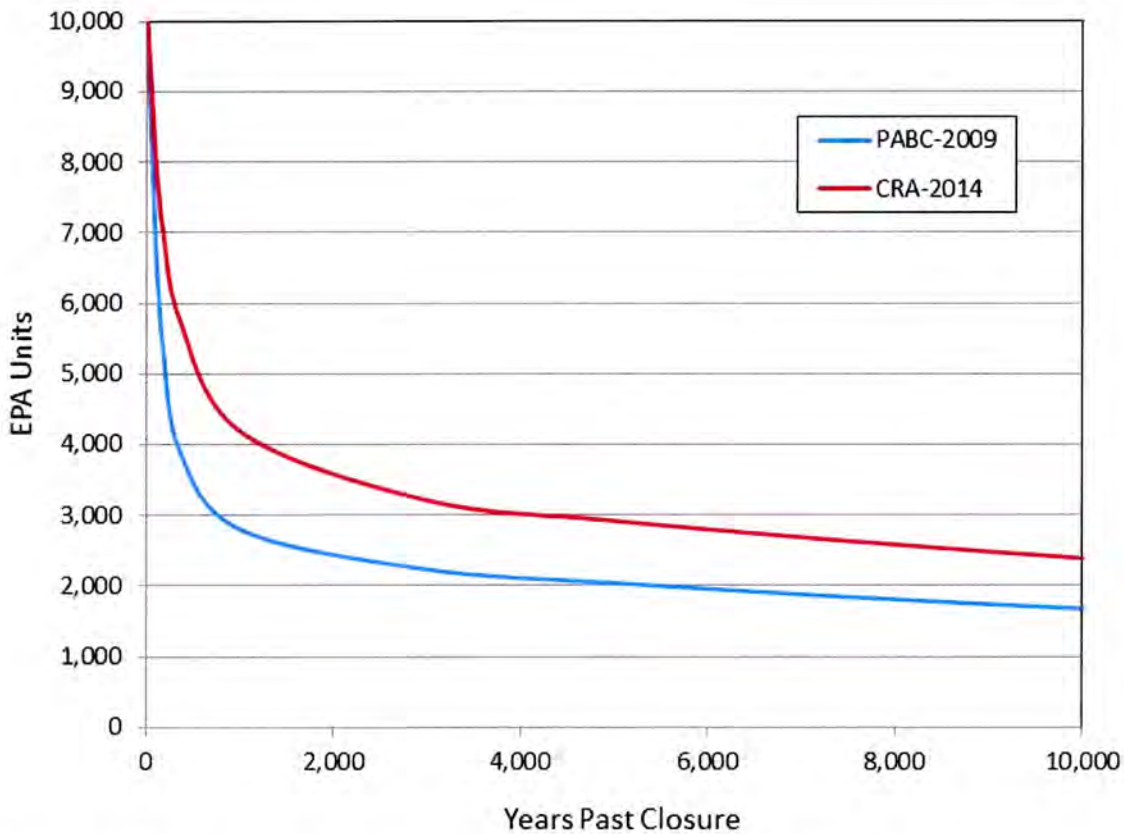
Another important result is the concentration of EPA Units per m^3 for each waste stream. Figure 4-1 illustrates the concentration of EPA Units per m^3 versus the cumulative volume percent for each waste stream at closure. As seen in Figure 4-1, almost 30% of the total volume in the repository contains less than 0.01 EPA Units per m^3 and almost 88% of the total volume in the repository contains less than 0.1 EPA Units per m^3. The maximum concentration for the CRA-2014 inventory, 3.00 EPA Units per m^3, is higher than the maximum for the inventory used for the PABC-2009 PA, 1.98 EPA Units per m^3 (Fox and Clayton 2010, Section 4.2). However, the waste stream from the inventory used for the CRA-2014 PA with a concentration of 3.00 EPA Units per m^3 has a relatively small volume of 0.21 m^3 for a total of 0.63 EPA Units. A more appropriate comparison of maximum concentration would be with the second-highest concentration of 1.62 EPA Units per m^3 (waste stream volume of 1.87 m^3), which is lower than the maximum concentration of the inventory used for the PABC-2009 PA (1.98 EPA Units per m^3 and a 18.7 m^3 waste stream volume).



NOTE: From EPAUNI output files, *EPU_CRA14BL_CH.DIA* and *EPU_CRA14BL_RH.DIA*.

Figure 4-1. WIPP CH- and RH-TRU Waste EPA Units per Volume versus Cumulative Volume Percent; Time 0 (Calendar Year 2033)

To assess how the updated inventory will affect the PA results, a comparison of the total EPA Units as a function of time for the CRA-2014 inventory compared with the inventory used for the PABC-2009 PA, can be used and is shown in Figure 4-2. As seen in Figure 4-2, the total EPA units for both inventories start at similar levels, but the CRA-2014 inventory is higher after approximately 100 years and then remains higher throughout the 10,000-year regulatory period, primarily due to an increase in ^{239}Pu inventory (see Section 4.3). This will increase the direct solids releases for the CRA-2014, as most of the intrusions into the repository occur at later times.

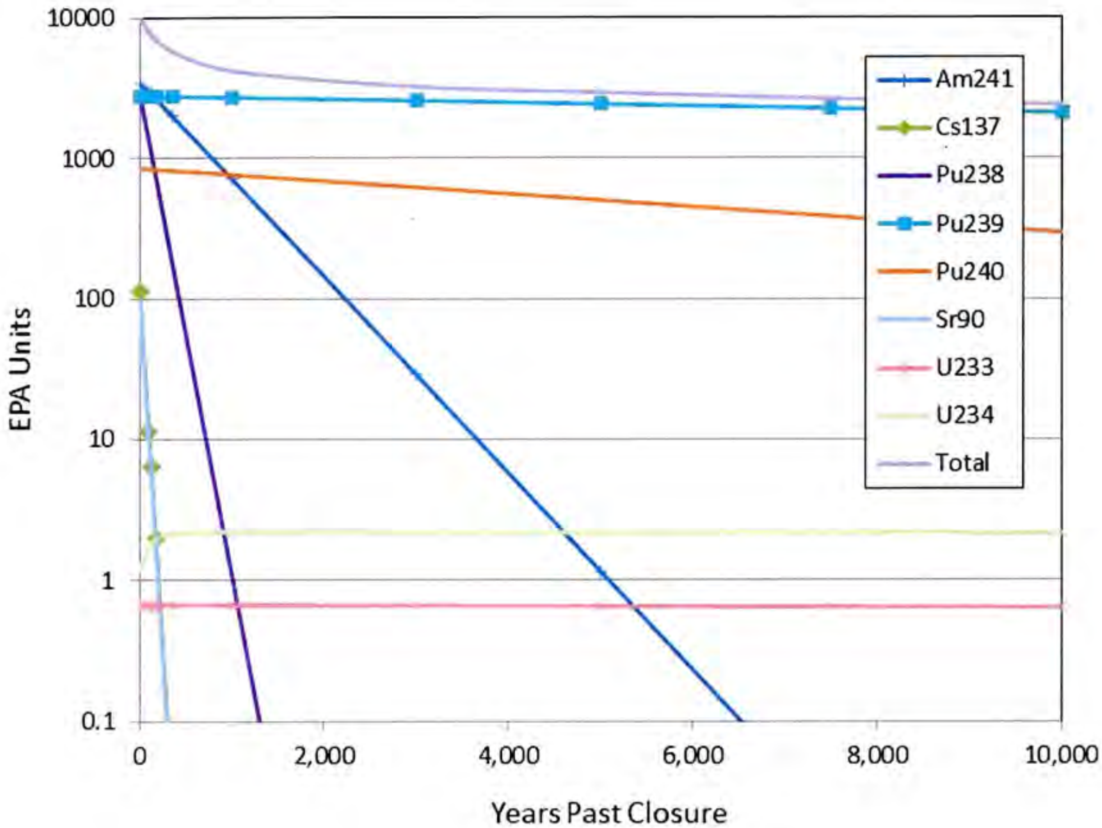


NOTES: The CRA-2014 data are from EPAUNI output files, *EPU_CRA14BL_CH.DIA* and *EPU_CRA14BL_RH.DIA*. The PABC-2009 data are from EPAUNI output files, *EPU_PABC09_CH.DIA* and *EPU_PABC09_RH.DIA*, as documented by Fox and Clayton (2010).

Figure 4-2. WIPP CH- and RH-TRU Waste EPA Units From Closure to 10,000 Years

4.3 ISOTOPES

Figure 4-3 shows the total EPA Units as a function of time for the CRA-2014, along with the individual radionuclides that contribute. As seen in Figure 4-3, the initial normalized activity of the inventory is dominated by ^{241}Am, ^{238}Pu, ^{239}Pu and ^{240}Pu. The ^{241}Am and ^{238}Pu decay rapidly and so the total normalized activity of the inventory is dominated at later times (> 2,000 years) by mainly ^{239}Pu with a smaller contribution from the ^{240}Pu. The ^{137}Cs, ^{90}Sr, ^{233}U and ^{234}U do not appreciably contribute to the total normalized activity at any time throughout the 10,000-year regulatory period. All 528 waste streams and their total normalized individual radionuclide activities can be found in the files *EPU_CRA14BL_CH_ACTIVITY.DIA* and *EPU_CRA14BL_RH_ACTIVITY.DIA* in the CMS library LIBCRA14_EPU.



NOTES: The Total EPA Units for each radionuclide is calculated as the sum of the CH and RH activity (in Ci) divided by the Release Limit (in Ci). The CH activity is from EPAUNI output file, *EPU_CRA14BL_CH_ACTIVITY.DIA* and the RH activity is from EPAUNI output file, *EPU_CRA14BL_RH_ACTIVITY.DIA*. The Release Limit is from Kicker and Zeitler (2013, Table A-1).

Figure 4-3. WIPP CH- and RH-TRU Waste Isotope Plot From Closure to 10,000 Years

5. REFERENCES

Camphouse, C. 2013. *Analysis Plan for the 2014 Compliance Recertification Application Performance Assessment*. AP-164. Sandia National Laboratories, Carlsbad, NM.

Clayton, D.J., S. Dunagan, J.W. Garner, A.E. Ismail, T.B. Kirchner, G.R. Kirkes, M.B. Nemer 2008. *Summary Report of the 2009 Compliance Recertification Application Performance Assessment*. Sandia National Laboratories, Carlsbad, NM. ERMS 548862.

Clayton, D.J., R.C. Camphouse, J.W. Garner, A.E. Ismail, T.B. Kirchner, K.L. Kuhlman, M.B. Nemer 2010. *Summary Report of the CRA-2009 Performance Assessment Baseline Calculation*. Sandia National Laboratories, Carlsbad, NM. ERMS 553039.

Cotsworth, E. 2005. *EPA Letter on Conducting the Performance Assessment Baseline Change (PABC) Verification Test*. U.S. EPA, Office of Radiation and Indoor Air, Washington, D.C. ERMS 538858.

Cotsworth, E. 2009. *EPA Letter on CRA-2009 First Set of Completeness Comments*. U.S. EPA, Office of Radiation and Indoor Air, Washington, D.C. ERMS 551444.

Fox, B. and D. Clayton 2010. *Analysis Package for EPA Unit Loading Calculations: CRA-2009 Performance Assessment Baseline Calculation*. Sandia National Laboratories, Carlsbad, NM. ERMS 552912.

Kicker, D.C. and T. Zeitler 2013. *Radionuclide Inventory Screening Analysis for the 2014 Compliance Recertification Application Performance Assessment (CRA-2014 PA)*. Sandia National Laboratories, Carlsbad, NM. ERMS 559257.

Leigh, C.D., J.F. Kanney, L.H. Brush, J.W. Garner, G.R. Kirkes, T. Lowry, M.B. Nemer, J.S. Stein, E.D. Vugrin, S. Wagner, and T.B. Kirchner 2005. *2004 Compliance Recertification Application Performance Assessment Baseline Calculation*, Revision 0. Sandia National Laboratories, Carlsbad, NM. ERMS 541521.

MacKinnon, R.J., and G. Freeze 1997a. *Summary of EPA-Mandated Performance Assessment Verification Test (Replicate 1) and Comparison With the Compliance Certification Application Calculations*, Revision 1. Sandia National Laboratories, Carlsbad, NM. ERMS 422595

MacKinnon, R.J., and G. Freeze 1997b. *Summary of Uncertainty and Sensitivity Analysis Results for the EPA-Mandated Performance Assessment Verification Test*, Revision 1. Sandia National Laboratories, Carlsbad, NM. ERMS 420669.

MacKinnon, R.J., and G. Freeze 1997c. *Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison With the Compliance Certification Application Calculations*, Revision 1. Sandia National Laboratories, Carlsbad, NM. ERMS 414880.

Sanchez, L.C., J. Liscum-Powell, J.S. Rath, and H.R. Trellue 1997. *WIPP PA Analysis Report for EPAUNI: Estimating Probability Distribution of EPA Unit Loading in the WIPP Repository for Performance Assessment Calculations, Version 1.01*. WBS 1.2.07.1.1. Sandia National Laboratories, Albuquerque, NM. ERMS # 243843.

U.S. Congress 1992. *WIPP Land Withdrawal Act*. Public Law 102-579, 106 Stat. 4777, 1992; as amended by Public Law 104-201, 110 Stat. 2422, 1996.

U.S. Department of Energy (DOE) 1996. *Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot.* DOE/CAO-1996-2184. U.S. Department of Energy, Carlsbad Area Office, Carlsbad, NM.

U.S. Department of Energy (DOE) 2004. *Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application for the Waste Isolation Pilot Plant.* DOE/WIPP 2004-3231. U.S. Department of Energy, Carlsbad Area Office, Carlsbad, NM.

U.S. Environmental Protection Agency (EPA) 1998. *40 CFR 194, Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the Disposal Regulations: Certification Decision: Final Rule.* Federal Register, Vol. 63, 27354-27406. ERMS 251924.

U.S. Environmental Protection Agency (EPA) 2006. *40 CFR 194, Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the Disposal Regulations: Certification Decision: Final Rule.* Federal Register, Vol. 71, 18010-18021.

U.S. Environmental Protection Agency (EPA) 2010. *40 CFR 194, Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the Disposal Regulations: Recertification Decision.* Federal Register No. 222, Vol. 75, pp. 70584-70595, November 18, 2010.