GTCC LLW ENVIRONMENTAL IMPACT STATEMENT: POST-CLOSURE PERFORMANCE DATA PACKAGE

Waste Isolation Pilot Plant

ADDENDUM A
GROUP 2 WASTES

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1. INTRODUCTION

This addendum to *GTCC LLW Environmental Impact Statement*, *Task 3.7*, *Post-Closure Assessment Data Package*, *Waste Isolation Pilot Plant* (SNL 2008a), addresses Group 2 and Group 3 wastes. The DOE has grouped waste into three categories to analyze the inventory in the Greater-than-Class-C (GTCC) Environmental Impact Statement (EIS). Group 1, which was addressed in the parent document cited above, includes commercial and DOE wastes that already exist or will be generated from existing facilities or activities, such as operating commercial nuclear utilities. Group 1 is comparable to the inventory presented in the Notice of Intent (NOI). Group 2, which is the focus of this addendum, represents the additional waste that was identified for inclusion in the EIS after the NOI was published, and consists of waste that may be generated from proposed actions. Group 3 includes wastes from the proposed Global Nuclear Energy Project (GNEP) programmatic alternatives and from the previously proposed Advanced Fuel Cycle Facility (AFCF) and will be qualitatively addressed in the cumulative impacts section of the GTCC EIS. The Group 3 waste stream from the previously proposed Advanced Fuel Cycle Facility (AFCF) is also analyzed in this addendum. The same methodology and assumptions contained in the parent document are used in this addendum, and the reader is referred to that document for additional detail.

The analysis contained in this addendum addresses the following GTCC low level waste (LLW) and DOE GTCC-like Group 2 waste streams:

- Waste stream 5 consists of GTCC activated metal from new commercial reactors;
- Waste stream 4b consists of DOE GTCC-like CH waste from the Radioisotope Power Systems (RPS);
- Waste stream 4d consists of DOE GTCC-like RH waste from the RPS;
- Waste stream 9a consists of activated metal and other RH waste from the West Valley NRC-Licensed Disposal Area (NDA);
- Waste stream 9b consists of waste from the West Valley State-Licensed Disposal Area (SDA); and
- Waste stream 9c consists of activated metal and other RH waste from the West Valley SDA.

Furthermore, the analysis contained in this addendum addresses the following GTCC LLW and DOE GTCC-like Group 3 waste streams:

- Waste stream 6a consists of DOE GTCC-like activated metal from the GNEP-AFCF;
- Waste stream 6b consists of DOE GTCC-like other contact-handled (CH) waste from the GNEP-AFCF;
- Waste stream 6c consists of DOE GTCC-like other remote-handled (RH) waste from the GNEP-AFCF.

Table 1 provides a summary of the volumes, container types and number of containers for the waste streams in Group 2 and Group 3 that are analyzed in this addendum. The methods and assumptions used to formulate the information summarized in Table 1 are documented in Argonne (2008). In addition, it is assumed that the disposal of Group 2 and Group 3 waste in the WIPP will receive regulatory approval and comply with appropriate Congressional mandates in place at the time of disposal. For additional information regarding the approach and assumptions, the reader is referred to Section 1.3 of SNL (2008a).

Table 1. Summary of Group 2 and Group 3 GTCC LLW and DOE GTCC-like Waste Volumes[a]

Waste Stream	ID	Description	Volume (m^3)	Container Type	Total Containers
4b	DOE	RPS DOE GTCC-like CH	875	55-gallon drum	4,207
4d	DOE	RPS DOE GTCC-like RH	385	h-SAMC	1,955
5	Com	New Commercial Reactors -GTCC Activated Metal	367	h-SAMC	5,317
9a	DOE	West Valley NDA - Activated Metal	210	h-SAMC	1,066
9a	DOE	West Valley NDA - Other RH	1,944	Lead shielded container	17,204
9b	DOE	West Valley SDA	1,552	SWB	826
9c	DOE	West Valley SDA - Activated Metal	525	h-SAMC	2,665
9c	DOE	West Valley SDA - Other RH	30	h-SAMC	152
6a	DOE	GNEP-AFCF DOE GTCC-like Activated Metal	328	h-SAMC	4,761
6b	DOE	GNEP-AFCF DOE GTCC-like Other CH Waste	23,870	SWB	12,697
6c	DOE	GNEP-AFCF DOE GTCC-like Other RH Waste	977	Lead shielded container	8,651

[a]All data taken from Argonne (2008). h-SAMC = half - Shielded Activated Metal Canister; SWB = Standard Waste Box.

Using the number of containers shown in Table 1 and the number of stacks per room for each container type, the number of WIPP disposal rooms required is calculated for each waste stream as documented in SNL (2008b). The number of WIPP disposal rooms required for each of the waste streams in Table 1 is shown in Table 2. Additional assumptions used to prepare the information presented in this report are discussed separately below in each section.

Table 2. WIPP Room Space Required for Group 2 and Group 3 GTCC LLW and DOE GTCC-like Waste Stream Disposal[a]

Waste Stream	Description	Container	Room Space Required
4b	RPS DOE GTCC-like CH	55-gallon drum	0.37
4d	RPS DOE GTCC-like RH	h-SAMC	0.70
5	New Commercial Reactors -GTCC Activated Metal	h-SAMC	1.89
9a	West Valley NDA - Activated Metal	h-SAMC	0.38
9a	West Valley NDA - Other RH	Lead shielded container	3.50
9b	West Valley SDA	SWB	0.50
9c	West Valley SDA - Activated Metal	h-SAMC	0.95
9c	West Valley SDA - Other RH	h-SAMC	0.05
6a	GNEP-AFCF DOE GTCC-like Activated Metal	h-SAMC	1.70
6b	GNEP-AFCF DOE GTCC-like Other CH Waste	SWB	7.75
6c	GNEP-AFCF DOE GTCC-like Other RH Waste	Lead shielded container	1.76

[a]Calculated in SNL (2008); [b]SAMC and AMC packages are not suitable for WIPP disposal and will not be considered in this analysis; Activated metals will be disposed in WIPP in h-SAMCs.

1.1 APPROACH

The approach used in the post-closure performance calculations for the Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste entails generating the incremental change in post-closure performance for each individual waste stream placed separately in the WIPP. Furthermore, the post-closure performance with the sum of Group 2 GTCC LLW and DOE GTCC-like waste placed in the WIPP, the sum of Group 1 and Group 2 and the sum of Group 1, Group 2 and Group 3 are evaluated. This leads to seven cases that were investigated for the addendum and are denoted 4G2, 5G2, 9G2, TG2, TG12, 6G3, and TG123.

Case 4G2	includes all of Group 2 waste stream 4 placed in 55-gallon drums and h-SAMCs.
Case 5G2	includes all of Group 2 waste stream 5 placed in h-SAMCs.
Case 9G2	includes all of Group 2 waste stream 9, placed in h-SAMCs and lead shielded containers.
Case TG2	is the sum of Cases 4G2, 5G2 and 9G2.
Case TG12	is the sum of Cases T (All Group 1 wastes, SNL 2008a) and TG2.
Case 6G3	includes all of Group 3 waste stream 6 placed in h-SAMCs, SWBs and lead shielded containers.
Case TG123	is the sum of Cases T (All Group 1 wastes, SNL 2008a), TG2 and 6G3.

As discussed in Section 2, the selection of important radionuclides using the Group 2 and Group 3 waste resulted in the same 13 radionuclides that resulted from the Group 1 waste radionuclide screening. Thus, the same assumptions and procedures were used for the Group 2 and Group 3 analysis, which also facilitated the analysis of Cases TG12 and TG123.

2. WASTE STREAM ANALYSIS

An analysis of the inventory was conducted to determine the radionuclides that would affect the post-closure performance calculations. The important radionuclides were screened in based on the half-life and activity level. In WIPP PA, it is assumed that institutional controls eliminate the possibility of a drilling intrusion for the first 100 years after closure. Therefore, radionuclides with half-lives less than 20 years are screened out, as over five half-lives (more including the time between waste placement and facility closure) will significantly reduce the activity. The 43 radionuclides reported for all the GTCC LLW and DOE GTCC-like waste in Group 2 and Group 3 (Argonne 2008) are shown in Table 3, along with their respective half-lives (KAPL 2002) and activity for each waste stream at the time of availability. Of the radionuclides listed in Table 3, ten have half-lives that are less than 20 years (^{3}H, ^{54}Mn, ^{55}Fe, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{228}Ra, ^{241}Pu and ^{244}Cm). The ^{3}H, ^{54}Mn, ^{55}Fe, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{155}Eu and ^{228}Ra radionuclides were screened out of the remaining analysis due to their short half-lives, but the ^{241}Pu and ^{244}Cm radionuclides were kept as they have decay products, ^{241}Am and ^{240}Pu (KAPL 2002), that have half-lives longer than 20 years.

Table 3. Radionuclide Activity for Group 2 and Group 3 GTCC LLW and DOE GTCC-like Waste Streams[a]

Radionuclide	Half-life (years)	Activity (Ci)				
		Waste Stream 4	Waste Stream 5	Waste Stream 9	Waste Stream 6	Total
^{3}H	1.23E+01	-	2.85E+03	2.28E+03	-	5.13E+03
^{14}C	5.72E+03	-	9.14E+03	5.71E+02	-	9.71E+03
^{54}Mn	8.54E-01	-	2.30E+04	2.91E+02	7.35E+05	7.58E+05
^{55}Fe	2.73E+00	-	1.69E+07	8.58E+03	1.36E+05	1.71E+07
^{59}Ni	7.60E+04	-	5.05E+04	1.13E+03	-	5.17E+04
^{60}Co	5.27E+00	-	2.26E+07	3.81E+04	-	2.26E+07
^{63}Ni	1.00E+02	-	7.13E+06	1.17E+05	-	7.24E+06
^{90}Sr	2.88E+01	2.22E+04	4.83E+03	1.18E+04	8.04E+02	3.96E+04
^{93}Mo	3.50E+03	-	4.63E+01	4.34E-02	-	4.64E+01
^{94}Nb	2.00E+04	-	2.52E+02	1.46E+01	-	2.67E+02
^{99}Tc	2.13E+05	-	1.79E+03	4.76E+00	-	1.80E+03
^{129}I	1.57E+07	-	7.58E-01	1.35E+00	-	2.10E+00
^{137}Cs	3.01E+01	6.55E+04	5.48E+03	2.71E+04	1.12E+03	9.92E+04
^{151}Sm	9.00E+01	-	-	2.00E+02	-	2.00E+02
^{152}Eu	1.35E+01	-	-	8.83E-01	-	8.83E-01
^{154}Eu	8.59E+00	-	-	8.01E+01	-	8.01E+01
^{155}Eu	4.75E+00	-	-	9.91E+00	-	9.91E+00
^{210}Pb	2.26E+01	-	-	5.94E-07	-	5.94E-07
^{226}Ra	1.60E+03	-	-	1.55E-06	-	1.55E-06
^{228}Ra	5.76E+00	-	-	3.19E-03	-	3.19E-03
^{227}Ac	2.18E+01	-	-	2.00E-02	-	2.00E-02
^{229}Th	7.30E+03	-	-	1.21E-02	-	1.21E-02

Table 3. Radionuclide Activity for Group 2 and Group 3 GTCC LLW and DOE GTCC-like Waste Streams[a] (continued)

Radionuclide	Half-life (years)	Activity (Ci)				
		Waste Stream 4	Waste Stream 5	Waste Stream 9	Waste Stream 6	Total
^{231}Pa	3.28E+04	-	-	3.03E-02	-	3.03E-02
^{232}Th	1.40E+10	-	-	3.24E-03	-	3.24E-03
^{232}U	6.98E+01	-	-	1.73E+00	-	1.73E+00
^{233}U	1.59E+05	-	-	3.77E+00	-	3.77E+00
^{234}U	2.46E+05	-	-	2.05E-01	-	2.05E-01
^{235}U	7.04E+08	-	-	7.28E-02	-	7.28E-02
^{236}U	2.34E+07	-	-	1.06E-01	-	1.06E-01
^{237}Np	2.14E+06	5.68E+00	-	6.73E-02	-	5.74E+00
^{238}U	4.47E+09	-	-	8.46E-01	-	8.46E-01
^{238}Pu	8.77E+01	3.02E+03	3.54E-01	2.46E+04	3.93E+02	2.80E+04
^{239}Pu	2.41E+04	4.37E+01	1.79E+03	3.02E+02	-	2.14E+03
^{240}Pu	6.56E+03	1.71E+01	-	2.04E+02	-	2.22E+02
^{241}Pu	1.44E+01	5.66E+02	1.02E+01	1.23E+04	3.57E+03	1.65E+04
^{241}Am	4.33E+02	7.60E+01	2.55E+01	7.19E+02	1.50E+02	9.71E+02
^{242}Pu	3.75E+05	-	-	1.81E-01	-	1.81E-01
^{243}Am	7.37E+03	-	-	1.14E+00	-	1.14E+00
^{243}Cm	2.91E+01	-	-	2.20E-01	-	2.20E-01
^{244}Cm	1.81E+01	-	-	1.65E+01	6.82E+02	6.98E+02
^{245}Cm	8.50E+03	-	-	7.97E-04	-	7.97E-04
^{246}Cm	4.76E+03	-	-	6.41E-05	-	6.41E-05

[a]All data taken from Argonne (2008).

Using the activity of the 35 remaining radionuclides, normalized by their respective release limits, the radionuclides were screened by determining which ones are necessary to capture the majority of the total activity. Table 4 shows the normalized activity of the 35 remaining radionuclides sorted by the total normalized activity values. The activities were normalized by dividing by their respective release limits to incorporate the fact that radionuclides with higher release limits are less important than radionuclides with lower release limits. For example, ^{63}Ni, ^{241}Am and ^{230}Th have release limits of 1,000, 100 and 10 EPA units, respectively and hence ten times the activity of ^{63}Ni is allowed compared to ^{241}Am and 100 times the activity of ^{63}Ni is allowed compared to ^{230}Th.

Table 4. Normalized Activity for Group 2 and Group 3 GTCC LLW and DOE GTCC-like Waste Streams

Radionuclide	Release limit (EPA unit)	Normalized Activity (Ci/EPA unit) [a]				
		Waste Stream 4	Waste Stream 5	Waste Stream 9	Waste Stream 6	Total
^{63}Ni	1,000	-	7.13E+03	1.17E+02	-	7.24E+03
^{238}Pu	100	3.02E+01	3.54E-03	2.46E+02	3.93E+00	2.80E+02
^{137}Cs	1,000	6.55E+01	5.48E+00	2.71E+01	1.12E+00	9.92E+01
^{14}C	100	-	9.14E+01	5.71E+00	-	9.71E+01
^{59}Ni	1,000	-	5.05E+01	1.13E+00	-	5.17E+01
^{90}Sr	1,000	2.22E+01	4.83E+00	1.18E+01	8.04E-01	3.96E+01
^{239}Pu	100	4.37E-01	1.79E+01	3.02E+00	-	2.14E+01
^{241}Am	100	7.60E-01	2.55E-01	7.19E+00	1.50E+00	9.71E+00
^{241}Pu	-	1.88E-01	3.38E-03	4.10E+00	1.19E+00	5.48E+00
^{240}Pu	100	1.71E-01	-	2.04E+00	-	2.22E+00
^{94}Nb	1,000	-	2.52E-01	1.46E-02	-	2.67E-01
^{151}Sm	1,000	-	-	2.00E-01	-	2.00E-01
^{99}Tc	10,000	-	1.79E-01	4.76E-04	-	1.80E-01
^{237}Np	100	5.68E-02	-	6.73E-04	-	5.74E-02
^{93}Mo	1,000	-	4.63E-02	4.34E-05	-	4.64E-02
^{233}U	100	-	-	3.77E-02	-	3.77E-02
^{129}I	100	-	7.58E-03	1.35E-02	-	2.10E-02
^{244}Cm	-	-	-	4.55E-04	1.88E-02	1.93E-02
^{232}U	100	-	-	1.73E-02	-	1.73E-02
^{243}Am	100	-	-	1.14E-02	-	1.14E-02
^{238}U	100	-	-	8.46E-03	-	8.46E-03
^{243}Cm	100	-	-	2.20E-03	-	2.20E-03
^{234}U	100	-	-	2.05E-03	-	2.05E-03
^{242}Pu	100	-	-	1.81E-03	-	1.81E-03
^{236}U	100	-	-	1.06E-03	-	1.06E-03
^{235}U	100	-	-	7.28E-04	-	7.28E-04
^{231}Pa	100	-	-	3.03E-04	-	3.03E-04
^{232}Th	100	-	-	3.24E-05	-	3.24E-05
^{227}Ac	1,000	-	-	2.00E-05	-	2.00E-05
^{230}Th	10	-	-	1.34E-05	-	1.34E-05
^{229}Th	1,000	-	-	1.21E-05	-	1.21E-05
^{245}Cm	100	-	-	7.97E-06	-	7.97E-06
^{246}Cm	100	-	-	6.41E-07	-	6.41E-07
^{226}Ra	1,000	-	-	1.55E-09	-	1.55E-09
^{210}Pb	1,000	-	-	5.94E-10	-	5.94E-10
Total		1.19E+02	7.30E+03	4.25E+02	8.57E+00	7.85E+03

[a]Activity from Table 3 divided by the release limit, sorted by the total column. [b]As there are no release limit for radionuclides with half-lives less than 20 years, the normalized release shown is the normalized release of the decay product, derived from the activity of the decay product, which is calculated from the equation $A_1 = A_2 \times \tau_2 \div \tau_1$, where A is the activity and τ is the half-life, divided by the decay product release limit.

To determine the radionuclides which are necessary to capture the majority of the total activity, the percent of the total normalized activity for each radionuclide in each waste was determined and is shown in Table 5. The radionuclides which did not contribute to at least 0.1% of the total activity were screened out (^{93}Mo, ^{94}Nb, ^{99}Tc, ^{129}I, ^{151}Sm, ^{210}Pb, ^{226}Ra, ^{227}Ac, ^{229}Th, ^{230}Th, ^{231}Pa, ^{232}Th, ^{232}U, ^{235}U, ^{236}U, ^{237}Np, ^{238}U, ^{242}Pu, ^{243}Am, ^{243}Cm, ^{245}Cm and ^{246}Cm). The radionuclides ^{240}Pu, ^{241}Pu, ^{233}U, ^{234}U and ^{244}Cm were retained, as these radionuclides are already incorporated into WIPP PA. After determining the screened in variables from the total normalized activity, the individual waste streams were examined to ensure no significant radionuclides were excluded. As seen in Table 5, the radionuclides that were screened out did not significantly contribute to any of the individual waste stream activities as well, which confirmed the radionuclide selection.

Table 5. Percent of Normalized Activity for Group 2 and Group 3 GTCC LLW and DOE GTCC-like Waste Streams[a]

Radionuclide	Waste Stream 4	Waste Stream 5	Waste Stream 9	Waste Stream 6	Total
^{63}Ni	-	90.78%	1.49%	-	92.27%
^{238}Pu	0.38%	0.00%	3.13%	0.05%	3.56%
^{137}Cs	0.83%	0.07%	0.35%	0.01%	1.26%
^{14}C	-	1.16%	0.07%	-	1.24%
^{59}Ni	-	0.64%	0.01%	-	0.66%
^{90}Sr	0.28%	0.06%	0.15%	0.01%	0.50%
^{239}Pu	0.01%	0.23%	0.04%	-	0.27%
^{241}Am	0.01%	0.00%	0.09%	0.02%	0.12%
^{241}Pu	0.00%	0.00%	0.05%	0.02%	0.07%
^{240}Pu	0.00%	-	0.03%	-	0.03%
^{94}Nb	-	0.00%	0.00%	-	0.00%
^{151}Sm	-	-	0.00%	-	0.00%
^{99}Tc	-	0.00%	0.00%	-	0.00%
^{237}Np	0.00%	-	0.00%	-	0.00%
^{93}Mo	-	0.00%	0.00%	-	0.00%
^{233}U	-	-	0.00%	-	0.00%
^{129}I	-	0.00%	0.00%	-	0.00%
^{244}Cm	-	-	0.00%	0.00%	0.00%
^{232}U	-	-	0.00%	-	0.00%
^{243}Am	-	-	0.00%	-	0.00%
^{238}U	-	-	0.00%	-	0.00%
^{243}Cm	-	-	0.00%	-	0.00%
^{234}U	-	-	0.00%	-	0.00%
^{242}Pu	-	-	0.00%	-	0.00%
^{236}U	-	-	0.00%	-	0.00%
^{235}U	-	-	0.00%	-	0.00%
^{231}Pa	-	-	0.00%	-	0.00%
^{232}Th	-	-	0.00%	-	0.00%

Table 5. Percent of Normalized Activity for Group 2 and Group 3 GTCC LLW and DOE GTCC-like Waste Streams[a] (continued)

Radionuclide	Waste Stream 4	Waste Stream 5	Waste Stream 9	Waste Stream 6	Total
^{227}Ac	-	-	0.00%	-	0.00%
^{230}Th	-	-	0.00%	-	0.00%
^{229}Th	-	-	0.00%	-	0.00%
^{245}Cm	-	-	0.00%	-	0.00%
^{246}Cm	-	-	0.00%	-	0.00%
^{226}Ra	-	-	0.00%	-	0.00%
^{210}Pb	-	-	0.00%	-	0.00%
Total	1.52%	92.95%	5.41%	0.11%	100.00%

[a]Normalized activity from Table 4 divided by the total shown in Table 4.

After the screening process, 13 radionuclide remain, ^{14}C, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{137}Cs, ^{233}U, ^{234}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, and ^{244}Cm, which have longer half-lives and contribute to the majority of the total activity of the GTCC LLW and DOE GTCC-like waste for WIPP PA. These are the same 13 as were selected for the Group 1 data. Table 6 shows the radionuclide activities, after the screening analyses, which were used for each waste stream in the post-closure performance calculations discussed below.

Table 6. Screened Radionuclide Activity for Group 2 and Group 3 GTCC LLW and DOE GTCC-like Waste Streams[a]

Radionuclide	Activity (Ci)				
	Waste Stream 4	Waste Stream 5	Waste Stream 9	Waste Stream 6	Total
^{14}C	-	9.14E+03	5.71E+02	-	9.71E+03
^{59}Ni	-	2.30E+04	2.91E+02	7.35E+05	7.58E+05
^{63}Ni	-	1.69E+07	8.58E+03	1.36E+05	1.71E+07
^{90}Sr	-	5.05E+04	1.13E+03	-	5.17E+04
^{137}Cs	-	2.26E+07	3.81E+04	-	2.26E+07
^{233}U	-	7.13E+06	1.17E+05	-	7.24E+06
^{234}U	2.22E+04	4.83E+03	1.18E+04	8.04E+02	3.96E+04
^{238}Pu	-	4.63E+01	4.34E-02	-	4.64E+01
^{239}Pu	-	2.52E+02	1.46E+01	-	2.67E+02
^{240}Pu	-	1.79E+03	4.76E+00	-	1.80E+03
^{241}Pu	-	7.58E-01	1.35E+00	-	2.10E+00
^{241}Am	6.55E+04	5.48E+03	2.71E+04	1.12E+03	9.92E+04
^{244}Cm	-	-	2.00E+02	-	2.00E+02

[a]Data from Table 3.

3. INPUT PARAMETERS

The combined f_w of each Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste stream with the WIPP inventory was used in the analysis and is shown in Table 7.

Table 7. The Individual and Combined "Unit of Waste" for Group 2 and Group 3 analysis.

	Case 4G2	**Case 5G2**	**Case 9G2**	**Case TG2**	**Case TG12[c]**	**Case 6G3**	**Case TG123[d]**
Individual f_w [a]	0.003	0.002	0.026	0.031	0.169	0.001	0.169
Combined f_w [b]	2.323	2.322	2.346	2.351	2.489	2.321	2.489

[a]Calculated from Equation 1.2 in SNL (2008a) and the activity from Table 6. [b]Calculated by adding 2.320 (the f_w for the WIPP inventory [Leigh and Trone 2005]) to the individual f_w. [c]Calculated by adding the individual f_w for Case T from SNL (2008a) to Case TG2. [d]Calculated by adding the individual f_w for Case T from SNL (2008a) to Case TG2 and Case 6G3.

3.1 PANEL

The script, input and output file names and locations for each code execution for the Group 2 and Group 3 PANEL analysis is shown below in Table 8.

Table 8. PANEL Code, Preprocessor and Post-Processor Script, Input and Output File Names and Locations for the Group 2 and Group 3 analysis.

Code/File Type	**File Names**	**Directory**
GENMESH		
Script	GM_PANEL_GTCC.COM	PANEL
Input	GM_PANEL_CRA1BC.INP	PANEL/PNLINP
Output	GM_PANEL_GTCC.CDB	PANEL/GMCDB
Output	GM_PANEL_GTCC.DBG	PANEL/GMCDB
MATSET		
Script	MS_PANEL_GTCC.COM	PANEL
Input	MS_PANEL_GTCC_*c*.INP	PANEL/PNLINP
Input	GM_PANEL_GTCC.CDB	PANEL/GMCDB
Output	MS_PANEL_GTCC_*c*.CDB	PANEL/MSCDB
Output	MS_PANEL_GTCC_*c*.DBG	PANEL/MSCDB
POSTLHS		
Script	LHS3_PANEL_GTCC.COM	PANEL
Input	LHS2_CRA1BC_R1.TRN	PANEL/PNLINP
Input	LHS3_DUMMY.INP	PANEL/PNLINP
Input	MS_PANEL_GTCC_*c*.CDB	PANEL/MSCDB
Output	LHS3_PANEL_GTCC_ *c*_V*vvv*.CDB	PANEL/LHS3CDB
Output	LHS3_PANEL_GTCC_ *c*.DBG	PANEL/LHS3CDB

Table 8. PANEL Code, Preprocessor and Post-Processor Script, Input and Output File Names and Locations for the Group 2 and Group 3 analysis. (continued)

Code/File Type	**File Names**	**Directory**
ALGEBRACDB		
Script	ALG_PANEL_GTCC.COM	PANEL
Input	ALG_PANEL_CRA1BC.INP	PANEL/PNLINP
Input	LHS3_PANEL_GTCC_ *c*_V*vvv*.CDB	PANEL/LHS3CDB
Output	ALG_PANEL_GTCC_ *c*_V*vvv*.CDB	PANEL/ALGCDB
Output	ALG_PANEL_GTCC_ *c*_V*vvv*.DBG	PANEL/ALGCDB
PANEL		
Script	PANEL_GTCC.COM	PANEL
Input	ALG_PANEL_GTCC_ *c*_V*vvv*.CDB	PANEL/ALGCDB
Output	PANEL_CON_GTCC_ *c*_S*s*_V*vvv*.CDB	PANEL/PNLCDB
Output	PANEL_CON_GTCC_ *c*_S*s*_V*vvv*.DBG	PANEL/PNLCDB
SUMMARIZE		
Script	SUM_GTCC.COM	PANEL
Input	SUM_PANEL_CON_GTCC_*c*_S*s*.INP	PANEL/SUMINP
Input	PANEL_CON_GTCC_ *c*_S*s*_V*vvv*.CDB	PANEL/PNLCDB
Output	SUM_PANEL_CON_GTCC_*c*_S*s*.TBL	PANEL/SUMTBL
Output	GTCC_*c*_S*s*.LOG	PANEL/SUMTBL

1. $c \in \{4G2, 5G2, 9G2, TG2, TG12, 6G3, TG123\}$
2. $s \in \{1, 2\}$ for each c
3. $vvv \in \{001, 002, ..., 100\}$ for each s

Of the input files listed in Table 8, only the MS_PANEL_GTCC_*c*.INP and SUM_PANEL_CON_GTCC_*c*_S*s*.INP files were modified from the existing baseline, CRA-2004 PABC, PANEL input files. The MS_PANEL_GTCC_*c*.INP files were modified to include the waste stream inventory and the updated f_w. The SUM_PANEL_CON_GTCC_*c*_S*s*.INP files were modified to use the correct file name and location of the PANEL_CON_GTCC_ *c*_S*s*_V*vvv*.CDB files. All other input files used are either input files used in the CRA-2004 PABC or output from a computer code.

3.2 EPAUNI

Using the equivalent radionuclides discussed in Section 3.2 of SNL (2008), input values for the activities of the 10 radionuclides modeled in the EPAUNI can be derived for the Group 2 and Group 3 waste and are shown in Table 9. The activities shown in Table 9 were used to modify the EPAUNI input files.

Table 9. Equivalent Radionuclide Activity (Ci) for Each Group 2 and Group 3 Case Used in EPAUNI[a]

Equivalent Radionuclide	Case 4G2	Case 5G2	Case 9G2	Case TG2	Case TG12[b]	Case 6G3	Case TG123[c]
^{90}Sr	2.22E+04	4.83E+03	1.18E+04	3.88E+04	1.30E+05	8.04E+02	1.30E+05
^{137}Cs	6.55E+04	5.48E+03	2.71E+04	9.81E+04	2.27E+06	1.12E+03	2.27E+06
^{233}U	0.00E+00	0.00E+00	3.77E+00	3.77E+00	8.08E+02	0.00E+00	8.08E+02
^{234}U[d]	0.00E+00	5.05E+03	1.13E+02	5.17E+03	1.80E+04	0.00E+00	1.80E+04
^{238}Pu[e]	3.02E+03	1.30E+06	4.60E+04	1.35E+06	4.65E+06	3.93E+02	4.65E+06
^{239}Pu	4.37E+01	1.79E+03	3.02E+02	2.14E+03	1.82E+04	0.00E+00	1.82E+04
^{240}Pu[f]	1.71E+01	9.14E+03	7.75E+02	9.93E+03	3.99E+04	0.00E+00	3.99E+04
^{241}Pu	5.66E+02	1.02E+01	1.23E+04	1.29E+04	8.98E+04	3.57E+03	8.98E+04
^{241}Am	7.60E+01	2.55E+01	7.19E+02	8.20E+02	6.95E+04	1.50E+02	6.95E+04
^{244}Cm	0.00E+00	0.00E+00	1.65E+01	1.65E+01	1.56E+03	6.82E+02	1.56E+03

[a]Based on data in Table 6. [b]Sum of Cases T from SNL (2008a) and TG2. [c]Sum of Cases T from SNL (2008a), TG2 and 6G3. [d]Sum of ^{234}U and ^{59}Ni/10 activities. [e]Sum of ^{238}Pu and 1.83/10 × ^{63}Ni activities. [f]Sum of ^{240}Pu and ^{14}C activities.

The script, input and output file names and locations for each code execution for the Group 2 and Group 3 EPAUNI analysis is shown below in Table 10.

Table 10. EPAUNI Code Script, Input and Output File Names and Locations for the Group 2 and Group 3 analysis.

Code/File Type	File Names	Directory
EPAUNI		
Script	EPU_GTCC.COM	EPAUNI
Input	EPU_GTCC_*c*_CH.INP	EPAUNI/EPUINP
Input	EPU_GTCC_*c*_CH_MISC.INP	EPAUNI/EPUINP
Output	EPU_GTCC_*c*_CH.DAT	EPAUNI/EPUDAT
Output	EPU_GTCC_*c*_CH.OUT	EPAUNI/EPUOUT
Output	EPU_GTCC_*c*_CH.OUT2	EPAUNI/EPUOUT
Output	EPU_GTCC_*c*_CH.DIA	EPAUNI/EPUOUT
Output	EPU_GTCC_*c*_CH_ACTIVITY.DIA	EPAUNI/EPUOUT

1. $c \in \{4G2, 5G2, 9G2, TG2, TG12, 6G3, TG123\}$

The EPU_GTCC_*c*_CH.INP files were modified to add the activity of the Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste for each case and the EPU_GTCC_*c*_CH_MISC.INP files were modified to include the updated f_w.

3.3 CCDFGF

The scaled CH area and scaled repository volume parameters for each Group 2 and Group 3 case are shown in Table 11. The scaled repository fraction occupied by waste parameter for each case is shown in Table 12.

Table 11. The Group 2 and Group 3 CH Area and Repository Volume Parameters Used in CCDFGF Calculations

Case	Rooms Needed[a]	CH area (m^2)[b]	Repository Volume (m^3)[c]
Case 4G2	1.07	1.133E+05	4.455E+05
Case 5G2	1.89	1.147E+05	4.508E+05
Case 9G2	5.38	1.205E+05	4.738E+05
Case TG2	8.34	1.255E+05	4.933E+05
Case TG12[d]	16.97	1.399E+05	5.501E+05
Case 6G3	11.21	1.303E+05	5.122E+05
Case TG123[e]	28.18	1.587E+05	6.239E+05

[a]From Table 2. [b]Calculated as 1.115E+05 × (1 + CH Rooms Needed ÷ 66.59). [c]Calculated as 4.384E+05 × (1 + CH Rooms Needed ÷ 66.59). [d]Sum of Cases T from SNL (2008a) and TG2. [e]Sum of Cases T from SNL (2008a), TG2 and 6G3.

Table 12. The Group 2 and Group 3 Repository Fraction Occupied by Waste Parameters Used in CCDFGF Calculations

Case	CH Waste Volume (m^3)[a]	Repository Fraction Occupied by Waste[b]
Case 4G2	1,260	0.382
Case 5G2	367	0.375
Case 9G2	4,261	0.365
Case TG2	5,888	0.354
Case TG12[c]	11,006	0.327
Case 6G3	25,175	0.379
Case TG123[d]	36,181	0.329

[a]From Argonne (2008). [b]Calculated as (4.384E+05 m^3 × 0.385 + GTCC CH waste volume) / scaled repository volume (Table 11); “Repository Fraction Occupied by Waste” is defined as the waste volume divided by the repository volume. [c]Sum of Cases T from SNL (2008a) and TG2. [d]Sum of Cases T from SNL (2008a), TG2 and 6G3.

The script, input and output file names and locations for each code execution for the Group 2 and Group 3 CCDFGF analysis is shown below in Table 13. Of the input files listed in Table 13, only the MS_CCGF_GTCC_*c*.INP file was modified to include the updated f_w, repository volume, CH effective area and repository fraction occupied by waste. All other input files used are either input files used in the CRA-2004 PABC or output from the computer codes previous discussed.

Table 13. CCDFGF Code and Preprocessor Script, Input and Output File Names and Locations for the Group 2 and Group 3 analysis.

Code/File Type	**File Names**	**Directory**
GENMESH		
Script	GM_CCGF_GTCC.COM	CCDFGF
Input	GM_CCGF_CRA1BC.INP	CCDFGF/CCGFINP
Output	GM_CCGF_GTCC.CDB	CCDFGF/GMCDB
Output	GM_CCGF_GTCC.DBG	CCDFGF/GMCDB
MATSET		
Script	MS_CCGF_GTCC.COM	CCDFGF
Input	MS_CCGF_GTCC_*c*.INP	CCDFGF/CCGFINP
Input	GM_CCGF_GTCC.CDB	CCDFGF/GMCDB
Output	MS_CCGF_GTCC_*c*.CDB	CCDFGF/MSCDB
Output	MS_CCGF_GTCC_*c*.DBG	CCDFGF/MSCDB
POSTLHS		
Script	LHS3_CCGF_GTCC.COM	CCDFGF
Input	LHS2_CRA1BC_R1.TRN	CCDFGF/CCGFINP
Input	LHS3_DUMMY.INP	CCDFGF/CCGFINP
Input	MS_CCGF_GTCC_*c*.CDB	CCDFGF/MSCDB
Output	LHS3_CCGF_GTCC_ *c*_V*vvv*.CDB	CCDFGF/LHS3CDB
Output	LHS3_CCGF_GTCC_ *c*.DBG	CCDFGF/LHS3CDB
PRECCDFGF		
Script	PRECCDFGF_GTCC.COM	CCDFGF
Input	MS_CCGF_GTCC_*c*.CDB	CCDFGF/MSCDB
Input	LHS3_CCGF_GTCC_ *c*_V*vvv*.CDB	CCDFGF/LHS3CDB
Input	SUM_PANEL_CON_GTCC_*c*_S*s*.TBL	PANEL/SUMTBL
Input	EPU_GTCC_*c*_CH.DAT	EPAUNI/EPUDAT
Input	EPU_CRA1BC_RH.DAT	CCDFGF/CRA1BCFILES
Input	INTRUSIONTIMES.IN	CCDFGF/CRA1BCFILES
Input	CUSP_CRA1BC_R1.TBL	CCDFGF/CRA1BCFILES
Input	SUM_DBR_CRA1BC_R1_S*s*_T*ttttt*_*d*.TBL	CCDFGF/CRA1BCFILES
Input	SUM_NUT_CRA1BC_R1_S1.TBL	CCDFGF/CRA1BCFILES
Input	SUM_NUT_CRA1BC_R1_S*s*_T*ttttt*.TBL	CCDFGF/CRA1BCFILES
Input	SUM_PANEL_INT_CRA1BC_R1_S6_T*ttttt*.TBL	CCDFGF/CRA1BCFILES
Input	SUM_PANEL_ST_CRA1BC_R1_S*s*.TBL	CCDFGF/CRA1BCFILES
Input	SUM_ST2D_CRA1BC_R1_M*m*.TBL	CCDFGF/CRA1BCFILES
Output	RELTAB_GTCC_*c*.DAT	CCDFGF/CCGFINP

Table 13. CCDFGF Code and Preprocessor Script, Input and Output File Names and Locations for the Group 2 and Group 3 analysis. (continued)

Code/File Type	File Names	Directory
CCDFGF		
Script	CCGF_GTCC.COM	CCDFGF
Input	CCGF_CRA1BC_CONTROL_R1.INP	CCDFGF/CCGFINP
Input	RELTAB_GTCC_*c*.DAT	CCDFGF/CCGFINP
Output	CCGF_GTCC_*c*.OUT	CCDFGF/CCGFOUT
Output	CCGF_GTCC_*c*.PRT	CCDFGF/CCGFOUT

1. $c \in \{\text{4G2, 5G2, 9G2, TG2, TG12, 6G3, TG123}\}$
2. $vvv \in \{\text{001, 002, ..., 100}\}$ for each c
3. $s \in \begin{cases} \{1, 2, 3, 4, 5\} \text{ for SUM\_DBR} \\ \{2, 3, 4, 5\} \text{ for SUM\_NUT} \\ \{1, 2\} \text{ for SUM\_PANEL\_ST} \\ \{1, 2\} \text{ for SUM\_PANEL\_CON for each } c \end{cases}$
4. $ttttt \in \begin{cases} \{00100, 00350, 01000, 03000, 05000, 10000\} \text{ for S1 for SUM\_DBR} \\ \{00550, 07500, 02000, 04000, 10000\} \text{ for S2, S4 for SUM\_DBR} \\ \{01200, 01400, 03000, 05000, 10000\} \text{ for S3, S5 for SUM\_DBR} \\ \{00100, 00350\} \text{ for S2, S4 for SUM\_NUT} \\ \{01000, 03000, 05000, 07000, 09000\} \text{ for S3, S5 for SUM\_NUT} \\ \{00100, 00350, 01000, 02000, 04000, 06000, 09000\} \text{ for SUM\_PANEL\_INT} \end{cases}$
5. $d \in \{\text{L, M, U}\}$ for each $ttttt$
6. $m \in \{\text{F, P}\}$

4. POST-CLOSURE PERFORMANCE RESULTS

The post-closure performance results show that including the total of Group 1, Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste in the WIPP repository will satisfy the three performance objectives stated in the GTCC EIS Task 3.4 document (SNL 2007). The WIPP repository has no significant MOP groundwater releases and adding the Group 1, Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste to the WIPP repository does not cause a significant MOP groundwater release. The incremental increases in the normalized releases to the IHI from adding the Group 1, Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste to the WIPP repository are not substantial enough to jeopardize the WIPP repository compliance with the release limits. The WIPP repository has long-term stability and adding the GTCC LLW and DOE GTCC-like waste does not adversely affect the long-term stability. More details of the post-closure performance results are discussed below.

4.1 UNDISTURBED RESULTS (MOP)

For WIPP PA, Salado transport calculations are performed for the undisturbed scenario to determine the concentration of radionuclides at receptor locations. The Salado transport calculations for the CRA-2004 PABC show negligible radionuclide concentrations at receptor locations, which are most likely due to numerical dispersion as a result of the finite-difference solution (Lowry 2005) and should be zero instead. As the addition of the Group 1, Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste to the WIPP inventory would increase the total radionuclide concentration by at most one order of magnitude (see Section 4.2.1), the undisturbed result from the CRA-2004 PABC Salado transport calculations is still applicable. Therefore, there are no releases to the MOP at the receptor locations with the addition of the Group 1, Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste to the WIPP repository.

4.2 DISTURBED RESULTS (IHI)

4.2.1 PANEL results

The PANEL code is a radionuclide waste-mobilization model designed specifically to model waste mobilization in the WIPP's wetted repository waste panels, and calculates the normalized release per volume for use in the groundwater transport and direct brine release mechanisms. The output from the PANEL code is the normalized release of radionuclide per volume of brine. The normalized release concentrations that resulted from the PANEL code with the addition of the GTCC LLW and DOE GTCC-like waste to the WIPP inventory are discussed below.

As the concentrations are used in the groundwater transport and direct brine release mechanism modeling, an increase in the concentration will result in an increase in the cumulative release. The normalized concentrations that resulted from the addition of Group 2 waste stream 5 showed a significant increase compared with the baseline WIPP PA, while the Group 2 waste streams 4 and 9 and Group 3 waste stream 6 showed little to no increase. The details of the PANEL results for the individual cases are given below.

4.2.1.1 Case 4G2 (RPS)

Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 4 to the WIPP inventory did not significantly increase the total radionuclide concentration. Figure 1 shows the total concentration as a function of time, comparing the results for Case 4G2 and the modified PANEL code with the PANEL version 4.03 results using the WIPP baseline inventory (Garner and Leigh 2005). Many radionuclides use a distribution for the solubility limit to capture the uncertainty, and so 100 sets with different solubility limits for those radionuclides are used, while for other radionuclides, a single solubility is used and so the same value is used in each of the 100 sets. The total concentration is a sum of all the radionuclide concentrations and so will generally decrease with time. As seen in Figure 1, the total concentration for the Case 4G2 is very similar to the WIPP baseline.

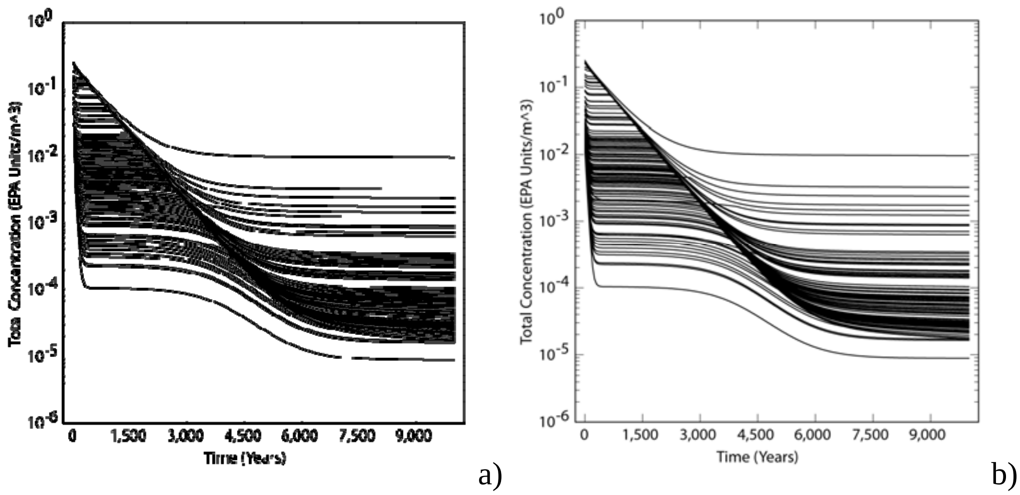


Figure 1. Total radionuclide concentration using the a) modified PANEL code with the Case 4G2 inventory and b) PANEL version 4.03 with the WIPP baseline inventory (Garner and Leigh 2005).

4.2.1.2 Case 5G2 (New Commercial Reactors)

Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 5 to the WIPP inventory increased the total radionuclide concentration significantly. Figure 2 shows the total concentration as a function of time, comparing the results for Case 5G2 and the modified PANEL code with the PANEL version 4.03 results using the WIPP baseline inventory (Garner and Leigh 2005). Many radionuclides use a distribution for the solubility limit to capture the uncertainty, and so 100 sets with different solubility limits for those radionuclides are used, while for other radionuclides, a single solubility is used and so the same value is used in each of the 100 sets. The total concentration is a sum of all the radionuclide concentrations and so will generally decrease with time. As seen in Figure 2, the total concentration for the Case 5G2 is always higher than the WIPP baseline in all of the 100 sets.

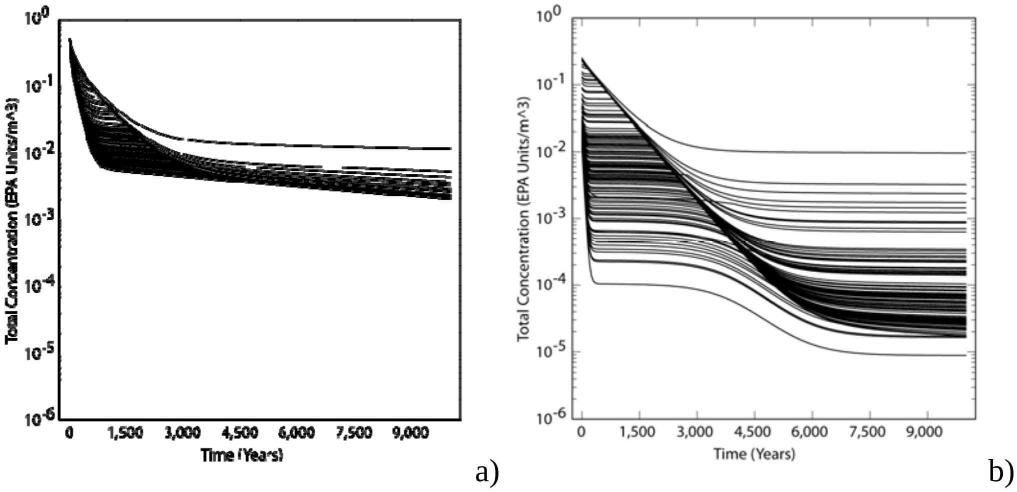


Figure 2. Total radionuclide concentration using the a) modified PANEL code with Case 5G2 inventory and b) PANEL version 4.03 with the WIPP baseline inventory (Garner and Leigh 2005).

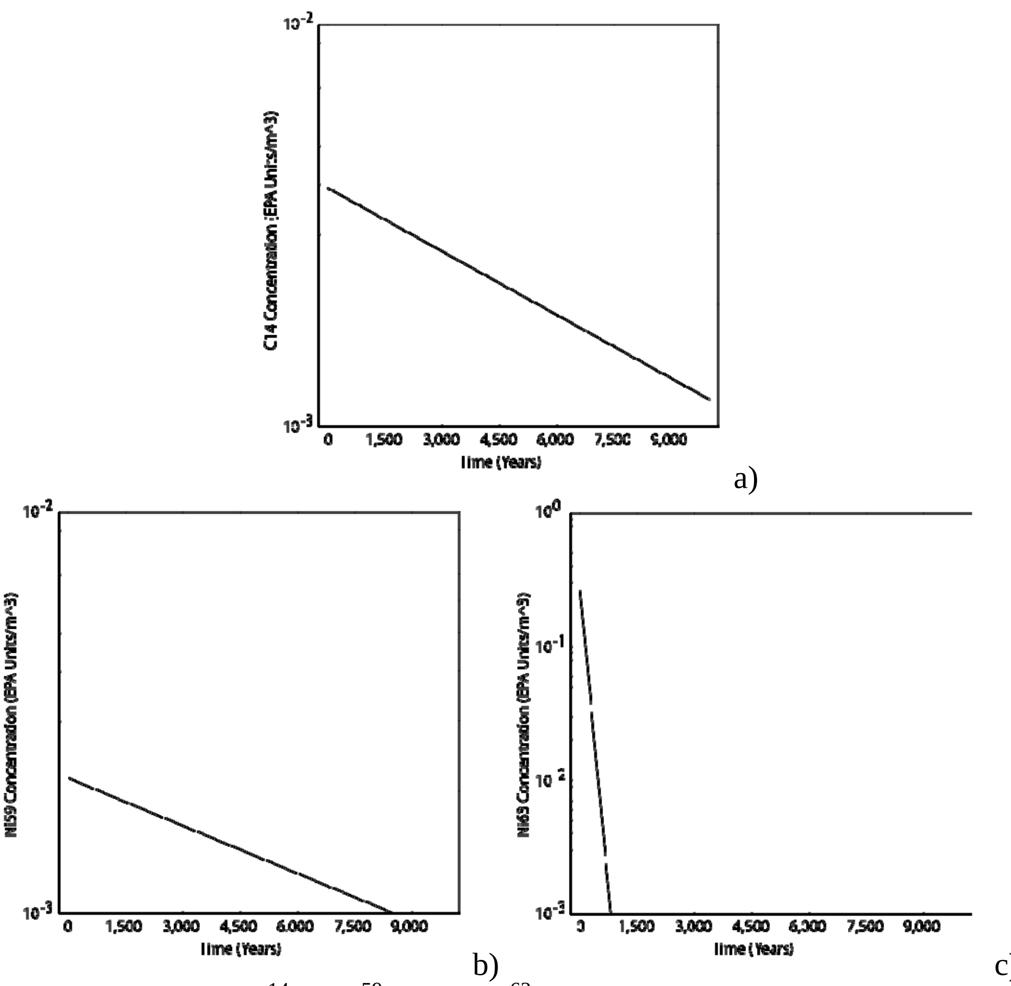


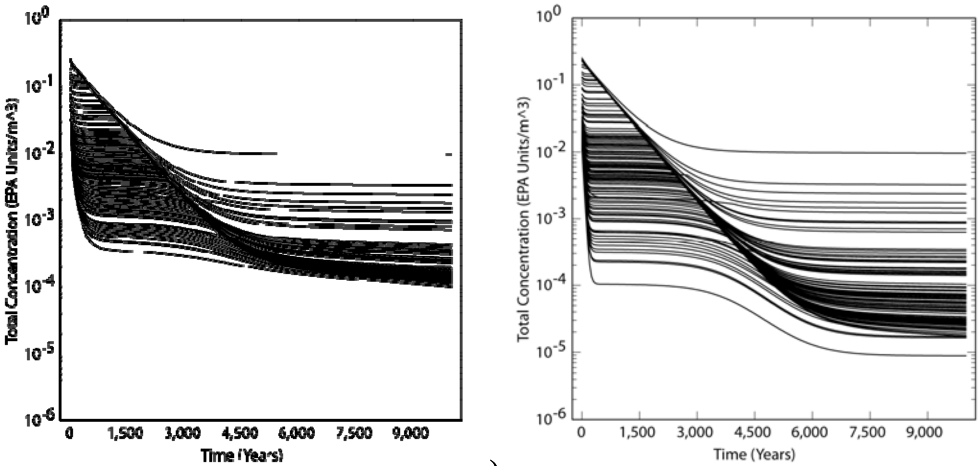
Figure 3. Concentration of a) ^{14}C, b) ^{59}Ni and c) ^{63}Ni using the modified PANEL code with Case 5G2 inventory.

The increase in the total concentration is mainly due to the ^{14}C, ^{59}Ni and ^{63}Ni in Group 2 waste stream 5. Figure 3 shows the normalized concentration of ^{14}C, ^{59}Ni and ^{63}Ni as a function of time for Case 5G2. A single solubility value is used for these radionuclides which is sufficiently high, such that the concentration is limited by the inventory and not the solubility limit. As seen in Figure 3, the concentrations of the ^{14}C, ^{59}Ni are of the order of 1.E-03 EPA Units/m^3, while the concentration of the ^{63}Ni starts out at ~3.E-01 EPA Units/m^3, but then sharply decreases. The effect from the ^{14}C, ^{59}Ni and ^{63}Ni on the total concentration for Case 5G2 can be seen in the minimum of the 100 sets, as it is dominated by the ^{63}Ni concentration for times before ~1,000 years and by the sum of the ^{14}C and ^{59}Ni concentrations for times after ~1,000 years (see Figure 2).

4.2.1.3 Case 9G2 (West Valley NDA/SDA)

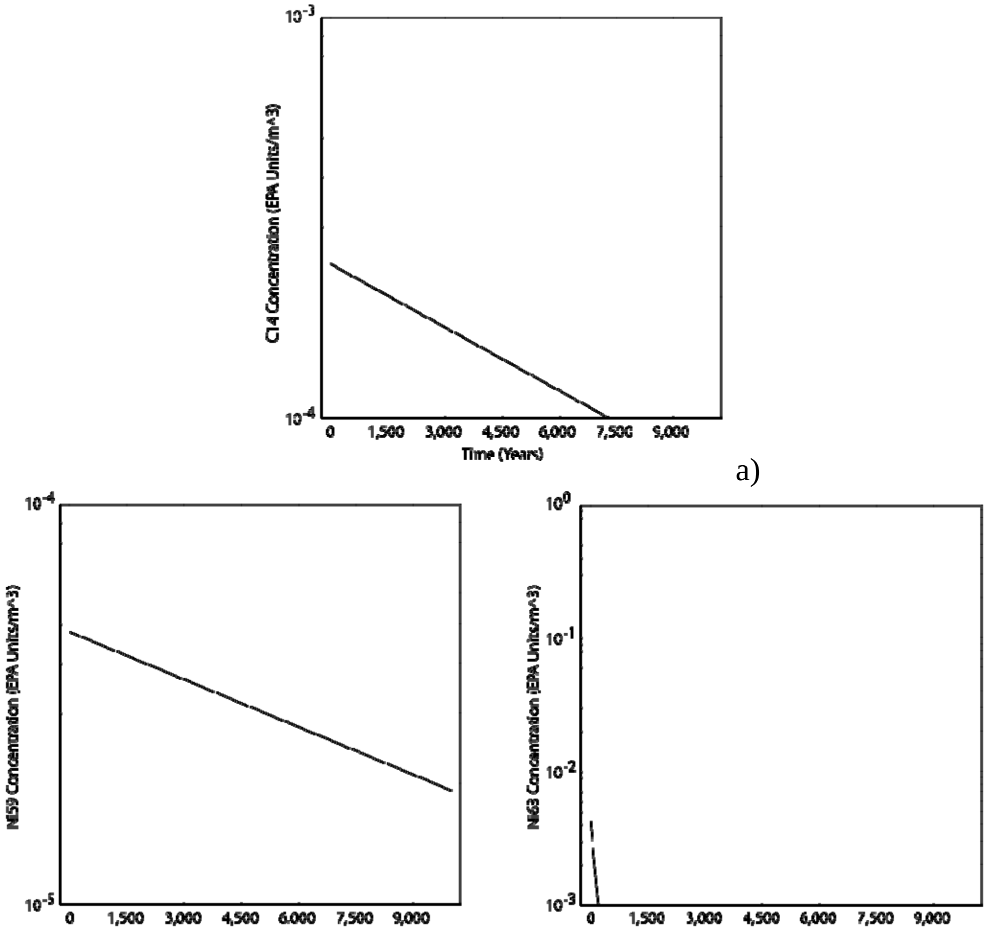
Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 9 to the WIPP inventory slightly increased the total radionuclide concentration. Figure 4 shows the total concentration as a function of time, comparing the results for Case 9G2 and the modified PANEL code with the PANEL version 4.03 results using the WIPP baseline inventory (Garner and Leigh 2005). Many radionuclides use a distribution for the solubility limit to capture the uncertainty, and so 100 sets with different solubility limits for those radionuclides are used, while for other radionuclides, a single solubility is used and so the same value is used in each of the 100 sets. The total concentration is a sum of all the radionuclide concentrations and so will generally decrease with time. As seen in Figure 4, the total concentration for the Case 9G2 is slightly increased compared to the WIPP baseline.

The increase in the total concentration is mainly due to the ^{14}C, ^{59}Ni and ^{63}Ni in Group 2 waste stream 9. Figure 5 shows the normalized concentration of ^{14}C, ^{59}Ni and ^{63}Ni as a function of time for Case 9G2. A single solubility value is used for these radionuclides which is sufficiently high, such that the concentration is limited by the inventory and not the solubility limit. As seen in Figure 5, the concentration of the ^{14}C is of the order of 1.E-04 EPA Units/m^3, the ^{59}Ni is of the order of 1.E-05 EPA Units/m^3, and the concentration of the ^{63}Ni starts out at ~4.E-03 EPA Units/m^3, but then sharply decreases. The effect from the ^{14}C, ^{59}Ni and ^{63}Ni on the total concentration for Case 9G2 can be seen in the minimum of the 100 sets, as it is dominated by the ^{63}Ni concentration for times before ~1,000 years and by the sum of the ^{14}C and ^{59}Ni concentrations for times after ~1,000 years (see Figure 4).



a) b)

Figure 4. Total radionuclide concentration using the a) modified PANEL code with Case 9G2 inventory and b) PANEL version 4.03 with the WIPP baseline inventory (Garner and Leigh 2005).



a) b) c)

Figure 5. Concentration of a) ^{14}C, b) ^{59}Ni and c) ^{63}Ni using the modified PANEL code with the Case 9G2 inventory.

4.2.1.4 Case TG2 (Group 2 Total)

Adding all the Group 2 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory significantly increased the total radionuclide concentration. Figure 6 shows the total concentration as a function of time for 100 sets, comparing the results for Case TG2 and the modified PANEL code with the PANEL version 4.03 results using the WIPP baseline inventory (Garner and Leigh 2005). Many radionuclides use a distribution for the solubility limit to capture the uncertainty, and so 100 sets with different solubility limits for those radionuclides are used, while for other radionuclides, a single solubility is used and so the same value is used in each of the 100 sets. The total concentration is a sum of all the radionuclide concentrations and so will generally decrease with time. As seen in Figure 6, the total concentration for the Case TG2 is significantly increased compared to the WIPP baseline. Case TG2 represents the sum of Cases 4G2, 5G2 and 9G2 and as Case 5G2 dominates the total activity of the Group 2 wastes (Table 5), the results are very similar to the results shown for Case 5G2.

The increase in the total concentration is mainly due to the ^{14}C, ^{59}Ni and ^{63}Ni in the waste streams. Figure 7 shows the normalized concentration of ^{14}C, ^{59}Ni and ^{63}Ni as a function of time for Case TG2. A single solubility value is used for these radionuclides which was sufficiently high, such that the concentration was limited by the inventory and not the solubility limit. As seen in Figure 7, the concentration of the ^{14}C ranges from 1.E-03 to 4.E-03 EPA Units/m^3, the ^{59}Ni concentration is of the order of 1.E-03 EPA Units/m^3, while the concentration of the ^{63}Ni starts out at ~3.E-01 EPA Units/m^3, but then sharply decreases. The effect from the ^{14}C, ^{59}Ni and ^{63}Ni on the total concentration for Case TG2 can be seen in the minimum of the 100 sets, as it is dominated by the ^{63}Ni concentration for times before ~1,000 years and by the sum of the ^{14}C and ^{59}Ni concentrations for times after ~1,000 years (see Figure 6).

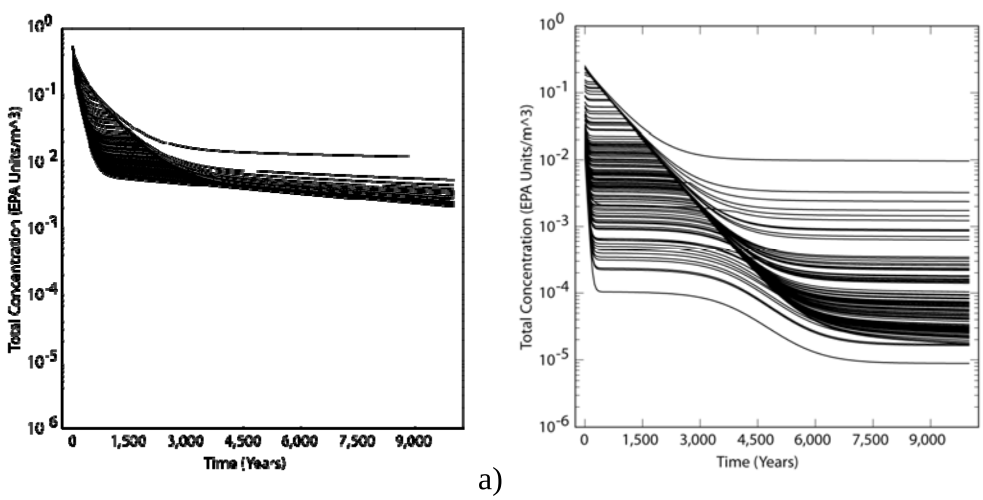


Figure 6. Total radionuclide concentration using the a) modified PANEL code with Case TG2 inventory and b) PANEL version 4.03 with the WIPP baseline inventory (Garner and Leigh 2005).

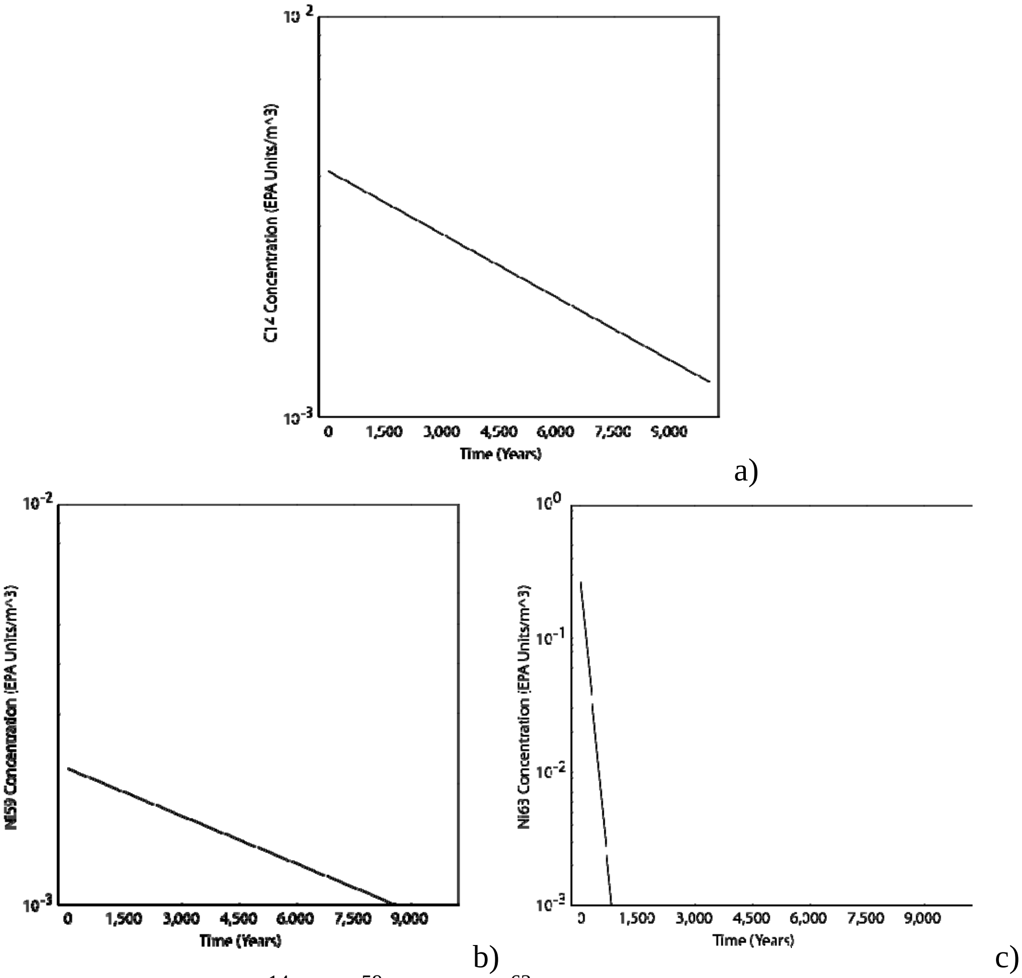


Figure 7. Concentration of a) ^{14}C, b) ^{59}Ni and c) ^{63}Ni using the modified PANEL code with Case TG2 inventory.

4.2.1.5 Case TG12 (Group 1 and Group 2 Total)

Adding both the Group 1 and Group 2 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory significantly increased the total radionuclide concentration. Figure 8 shows the total concentration as a function of time for 100 sets, comparing the results for Case TG12 and the modified PANEL code with the PANEL version 4.03 results using the WIPP baseline inventory (Garner and Leigh 2005). Many radionuclides use a distribution for the solubility limit to capture the uncertainty, and so 100 sets with different solubility limits for those radionuclides are used, while for other radionuclides, a single solubility is used and so the same value is used in each of the 100 sets. The total concentration is a sum of all the radionuclide concentrations and so will generally decrease with time. As seen in Figure 8, the total concentration for the Case TG12 is significantly increased compared to the WIPP baseline. Case TG12 represents the sum of Cases 1, 2, 3, 4, 4G2, 5G2 and 9G2 and as Cases 1 and 5G2 dominate the total activity, the results are very similar to the results shown for Cases 1 and 5G2.

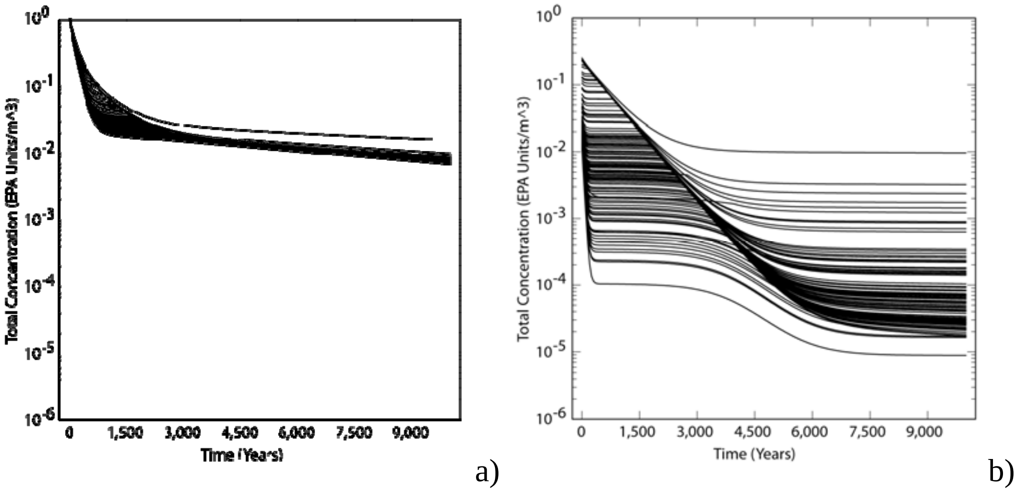


Figure 8. Total radionuclide concentration using the a) modified PANEL code with Case TG12 inventory and b) PANEL version 4.03 with the WIPP baseline inventory (Garner and Leigh 2005).

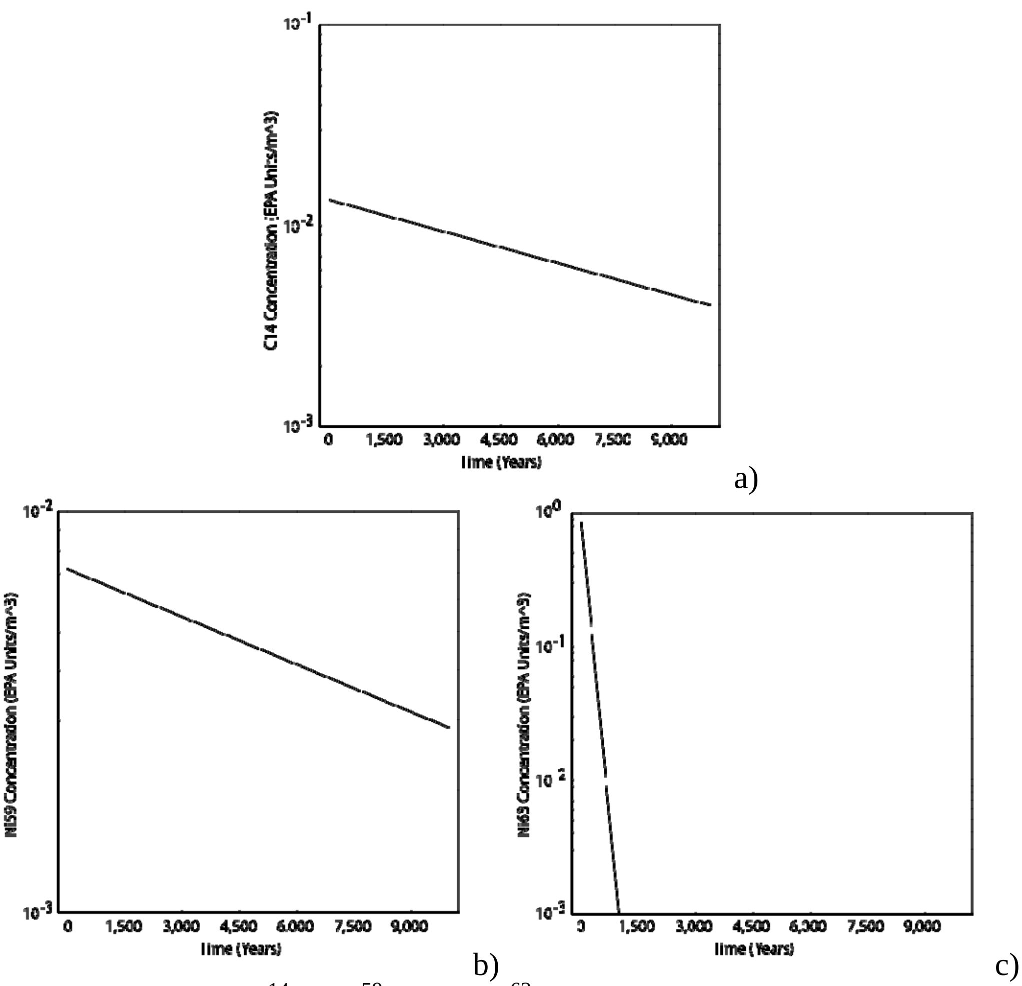


Figure 9. Concentration of a) ^{14}C, b) ^{59}Ni and c) ^{63}Ni using the modified PANEL code with Case TG12 inventory.

The increase in the total concentration is mainly due to the ^{14}C, ^{59}Ni and ^{63}Ni in the waste streams. Figure 9 shows the normalized concentration of ^{14}C, ^{59}Ni and ^{63}Ni as a function of time for Case TG12. A single solubility value is used for these radionuclides which was sufficiently high, such that the concentration was limited by the inventory and not the solubility limit. As seen in Figure 9, the concentration of the ^{14}C ranges from 2.E-03 to 9.E-03 EPA Units/m^3, the ^{59}Ni concentration is of the order of 1.E-03 EPA Units/m^3, while the concentration of the ^{63}Ni starts out at ~5.E-01 EPA Units/m^3, but then sharply decreases. The effect from the ^{14}C, ^{59}Ni and ^{63}Ni on the total concentration for Case TG12 can be seen in the minimum of the 100 sets, as it is dominated by the ^{63}Ni concentration for times before ~1,000 years and by the sum of the ^{14}C and ^{59}Ni concentrations for times after ~1,000 years (see Figure 8).

4.2.1.6 Case 6G3 (GNEP-AFCF)

Adding Group 3 GTCC LLW and DOE GTCC-like waste stream 6 to the WIPP inventory did not significantly increase the total radionuclide concentration. Figure 10 shows the total concentration as a function of time, comparing the results for Case 6G3 and the modified PANEL code with the PANEL version 4.03 results using the WIPP baseline inventory (Garner and Leigh 2005). Many radionuclides use a distribution for the solubility limit to capture the uncertainty, and so 100 sets with different solubility limits for those radionuclides are used, while for other radionuclides, a single solubility is used and so the same value is used in each of the 100 sets. The total concentration is a sum of all the radionuclide concentrations and so will generally decrease with time. As seen in Figure 10, the total concentration for the Case 6G3 is very similar to the WIPP baseline.

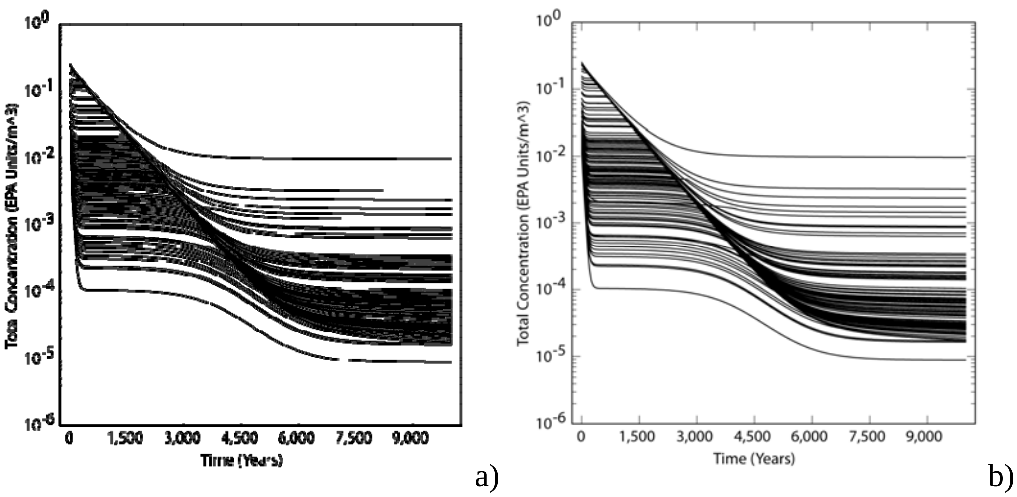
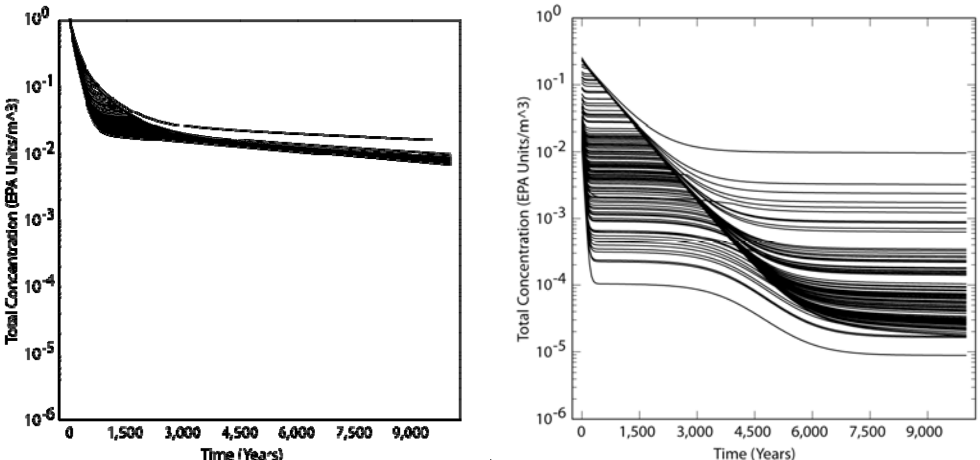


Figure 10. Total radionuclide concentration using the a) modified PANEL code with Case 6G3 inventory and b) PANEL version 4.03 with the WIPP baseline inventory (Garner and Leigh 2005).

4.2.1.7 Case TG123 (Group 1, Group 2 and Group 3 Total)

Adding the Group 1, Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory significantly increased the total radionuclide concentration. Figure 11 shows the total concentration as a function of time for 100 sets, comparing the results for Case TG123 and the modified PANEL code with the PANEL version 4.03 results using the WIPP baseline inventory (Garner and Leigh 2005). Many radionuclides use a distribution for the solubility limit to capture the uncertainty, and so 100 sets with different solubility limits for those radionuclides are used, while for other radionuclides, a single solubility is used and so the same value is used in each of the 100 sets. The total concentration is a sum of all the radionuclide concentrations and so will generally decrease with time. As seen in Figure 11, the total concentration for the Case TG123 is significantly increased compared to the WIPP baseline. Case TG123 represents the sum of Cases 1, 2, 3, 4, 4G2, 5G2, 9G2 and 6G3 and as Cases 1 and 5G2 dominate the total activity, the results are very similar to the results shown for Cases 1 and 5G2.



a) b)

Figure 11. Total radionuclide concentration using the a) modified PANEL code with Case TG123 inventory and b) PANEL version 4.03 with the WIPP baseline inventory (Garner and Leigh 2005).

The increase in the total concentration is mainly due to the ^{14}C, ^{59}Ni and ^{63}Ni in the waste streams. Figure 12 shows the normalized concentration of ^{14}C, ^{59}Ni and ^{63}Ni as a function of time for Case TG123. A single solubility value is used for these radionuclides which was sufficiently high, such that the concentration was limited by the inventory and not the solubility limit. As seen in Figure 12, the concentration of the ^{14}C ranges from 2.E-03 to 9.E-03 EPA Units/m^3, the ^{59}Ni concentration is of the order of 1.E-03 EPA Units/m^3, while the concentration of the ^{63}Ni starts out at ~5.E-01 EPA Units/m^3, but then sharply decreases. The effect from the ^{14}C, ^{59}Ni and ^{63}Ni on the total concentration for Case TG123 can be seen in the minimum of the 100 sets, as it is dominated by the ^{63}Ni concentration for times before ~1,000 years and by the sum of the ^{14}C and ^{59}Ni concentrations for times after ~1,000 years (see Figure 11).

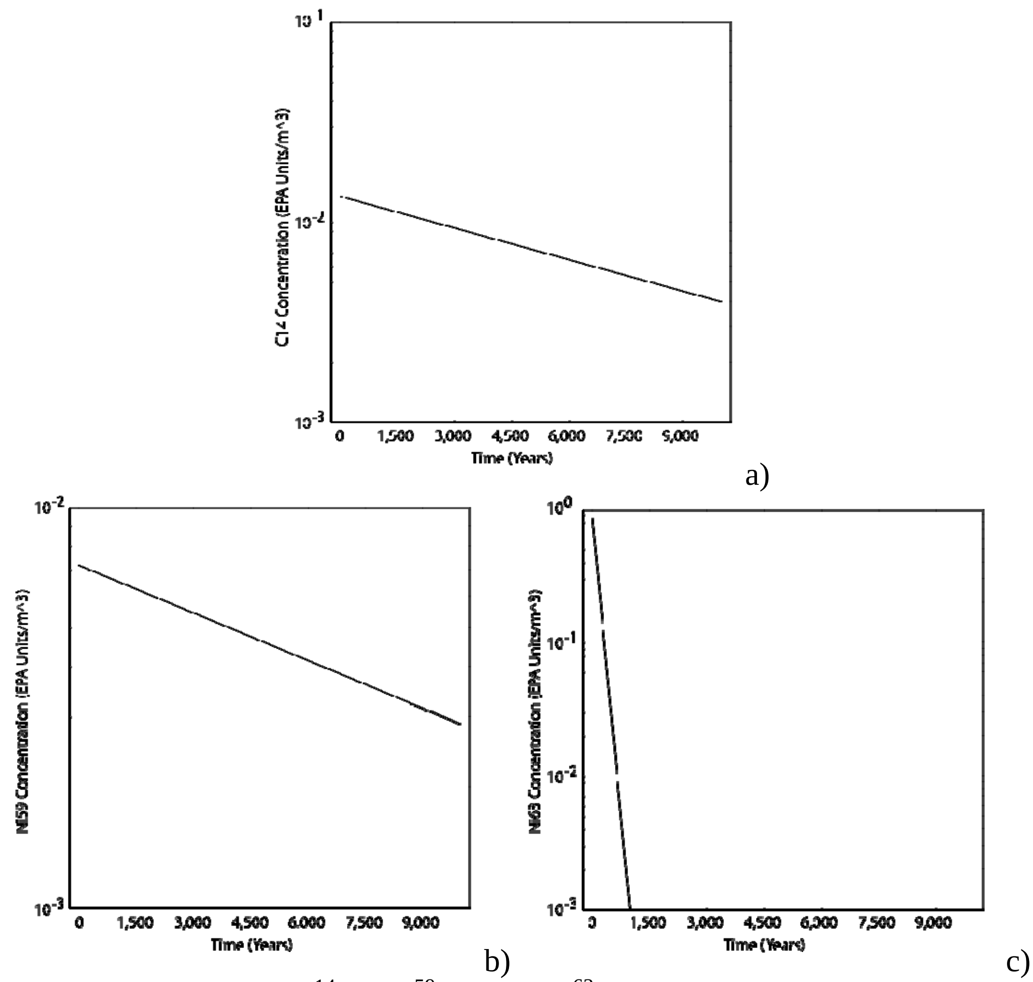


Figure 12. Concentration of a) ^{14}C, b) ^{59}Ni and c) ^{63}Ni using the modified PANEL code with Case TG123 inventory.

4.2.2 EPAUNI results

The EPAUNI code is the computational code that generates the normalized activity per volume as a function of time for use in calculating potential direct solid releases from the repository. The output from the EPAUNI code is the normalized release of radionuclide per volume of solid released. The normalized release concentrations that resulted from the EPAUNI code with the addition of the GTCC LLW and DOE GTCC-like waste to the WIPP inventory are discussed below.

As the concentrations are used in the direct solid release mechanism modeling, an increase in the concentration will result in an increase in the cumulative release. The normalized concentrations that resulted from the addition of the Group 2 waste streams showed a slight decrease and the addition of the Group 3 waste stream showed a significant decrease compared with the baseline WIPP PA. The details of the EPAUNI results for each case are given below. For ease of discussion, the EPAUNI code results for the CH and RH waste are combined together below.

4.2.2.1 Case 4G2 (RPS)

Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 4 to the WIPP inventory did not significantly affect the total radionuclide concentration. The average normalized activity for solid releases as a function of time for Case 4G2 compared with the results from the CRA-2004 PABC are shown in Figure 13. There is no significant difference between the two curves for the entire 10,000 year period.

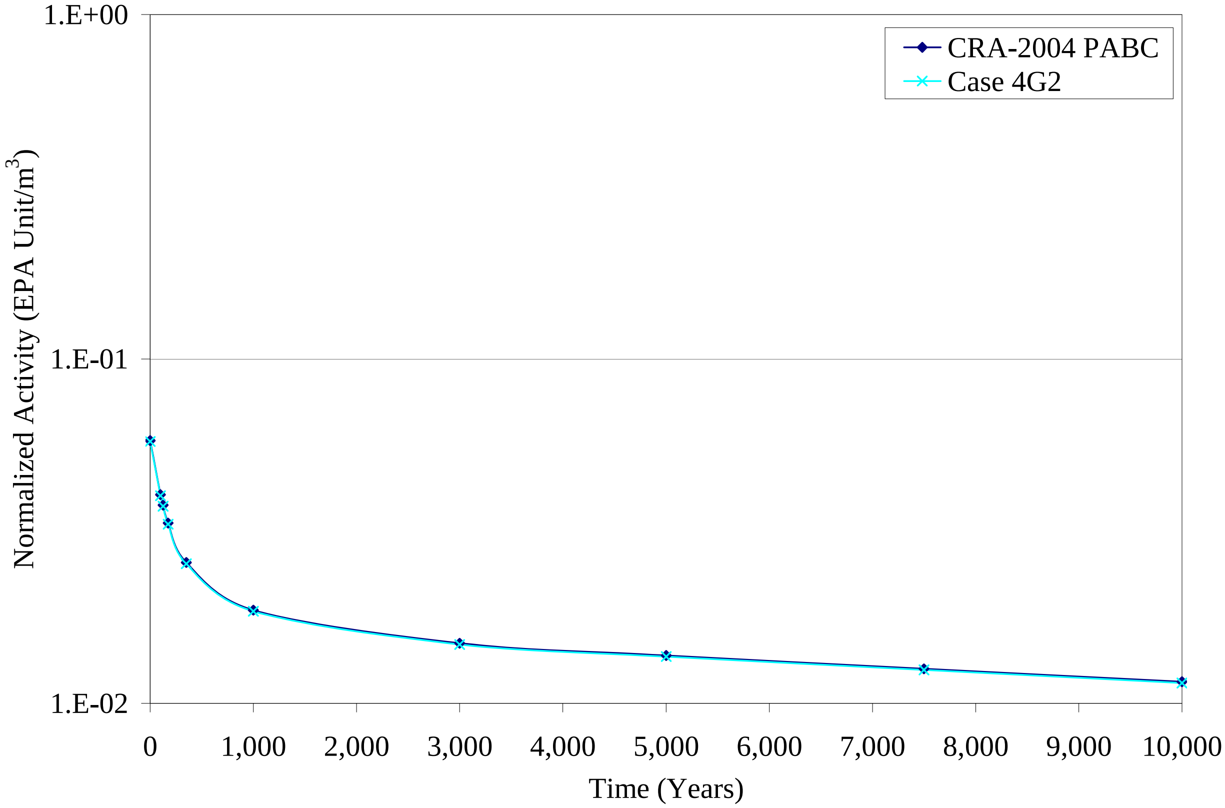


Figure 13. Normalized activity for solid releases as a function of time for Case 4G2 compared with the CRA-2004 PABC (Fox 2005).

4.2.2.2 Case 5G2 (New Commercial Reactors)

Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 5 to the WIPP inventory slightly increased the total radionuclide concentration. The average normalized activity for solid releases as a function of time for Case 5G2 compared with the results from the CRA-2004 PABC are shown in Figure 14. The difference between the two curves is the greatest at 0 years and decreases dramatically by 1,000 years where the difference remains fairly constant with time.

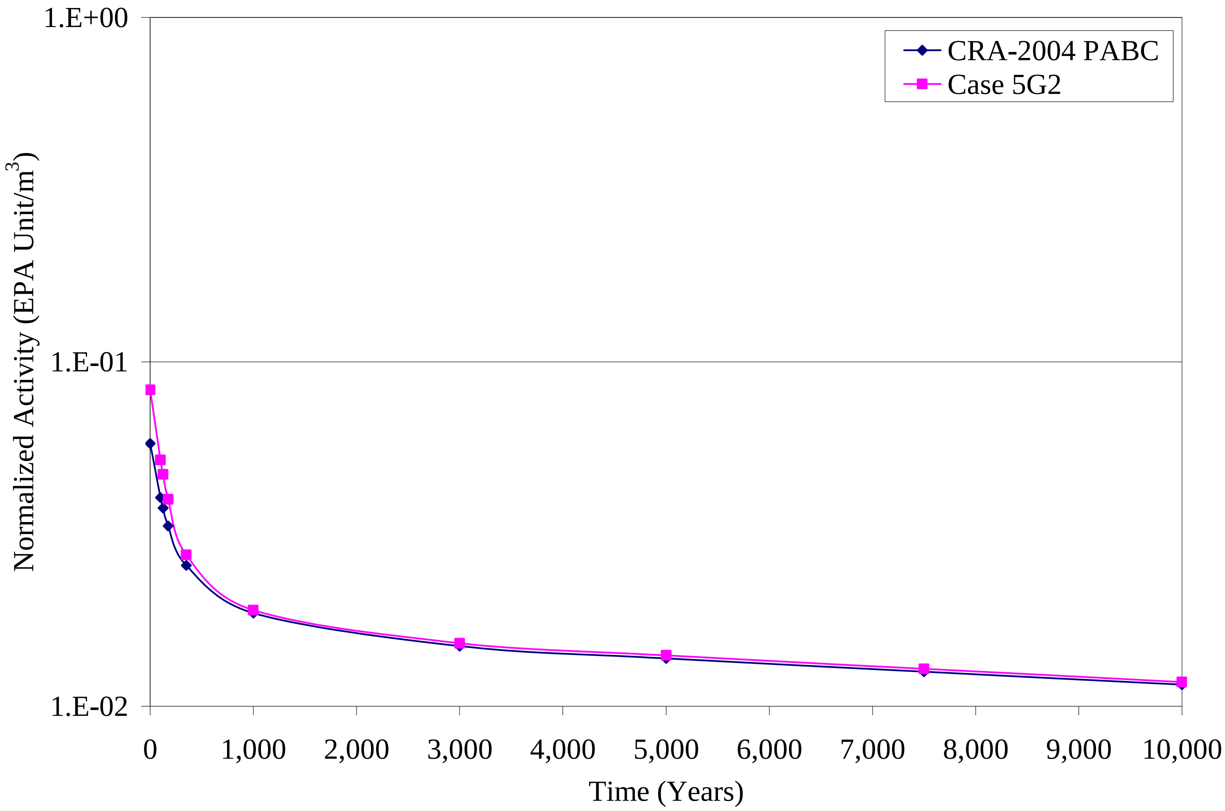


Figure 14. Normalized activity for solid releases as a function of time for Case 5G2 compared with the CRA-2004 PABC (Fox 2005).

4.2.2.3 Case 9G2 (West Valley NDA/SDA)

Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 9 to the WIPP inventory slightly decreased the total radionuclide concentration. The average normalized activity for solid releases as a function of time for Case 9G2 compared with the results from the CRA-2004 PABC are shown in Figure 15. The normalized activity for Case 9G2 is always slightly lower than the CRA-2004 PABC. The decrease in total radionuclide concentration is due mainly to the lower concentration of radionuclide per volume in Group 2 waste stream 9.

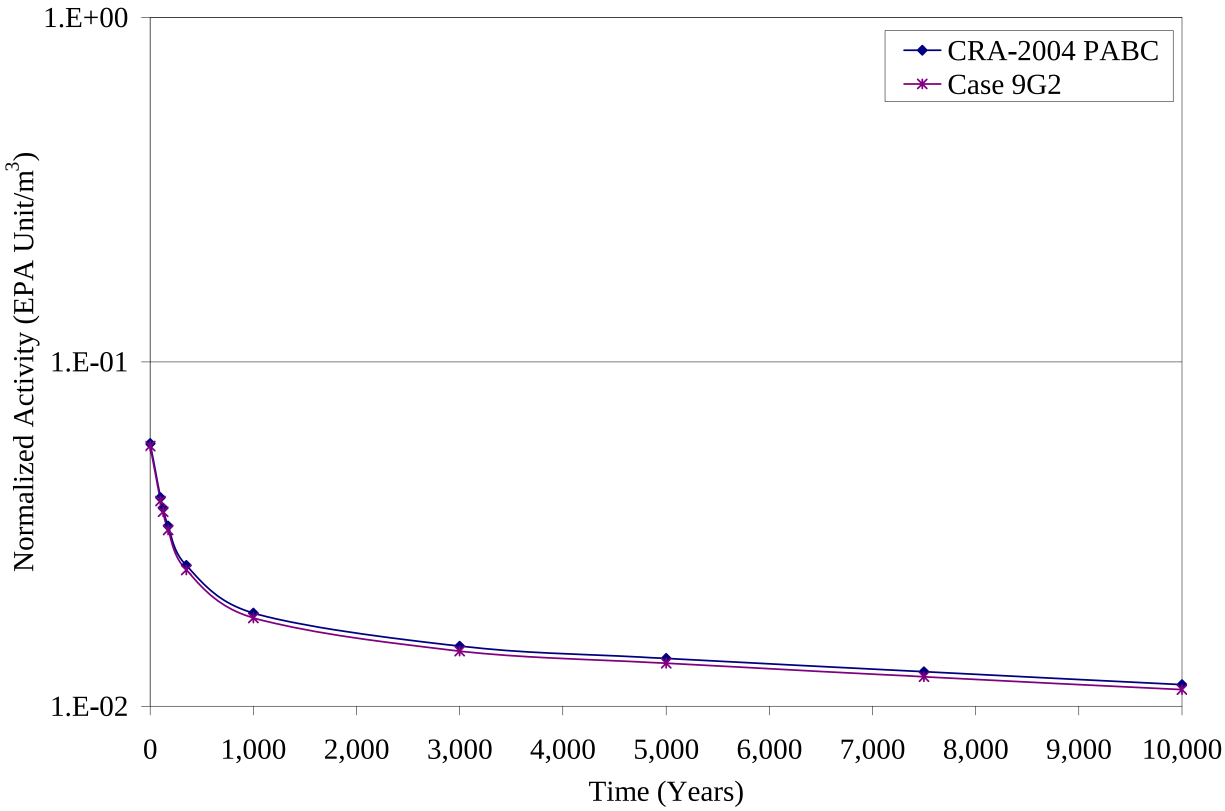


Figure 15. Normalized activity for solid releases as a function of time for Case 9G2 compared with the CRA-2004 PABC (Fox 2005).

4.2.2.4 Case TG2 (Group 2 Total)

Adding all the Group 2 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory generally slightly decreased the total radionuclide concentration. The average normalized activity for solid releases as a function of time for Case TG2 compared with the results from the CRA-2004 PABC are shown in Figure 16. At 0 years, the total radionuclide concentration is higher for Case TG2 compared with the CRA-2004 PABC and while after ~600 years, the total radionuclide concentration is slightly lower for Case TG2 versus the CRA-2004 PABC. Case TG2 represents the sum of Cases 4G2, 5G2 and 9G2 and as Case 9G2 dominates the total volume of Group 2 (Table 1), the results are very similar to the results shown for Case 9G2.

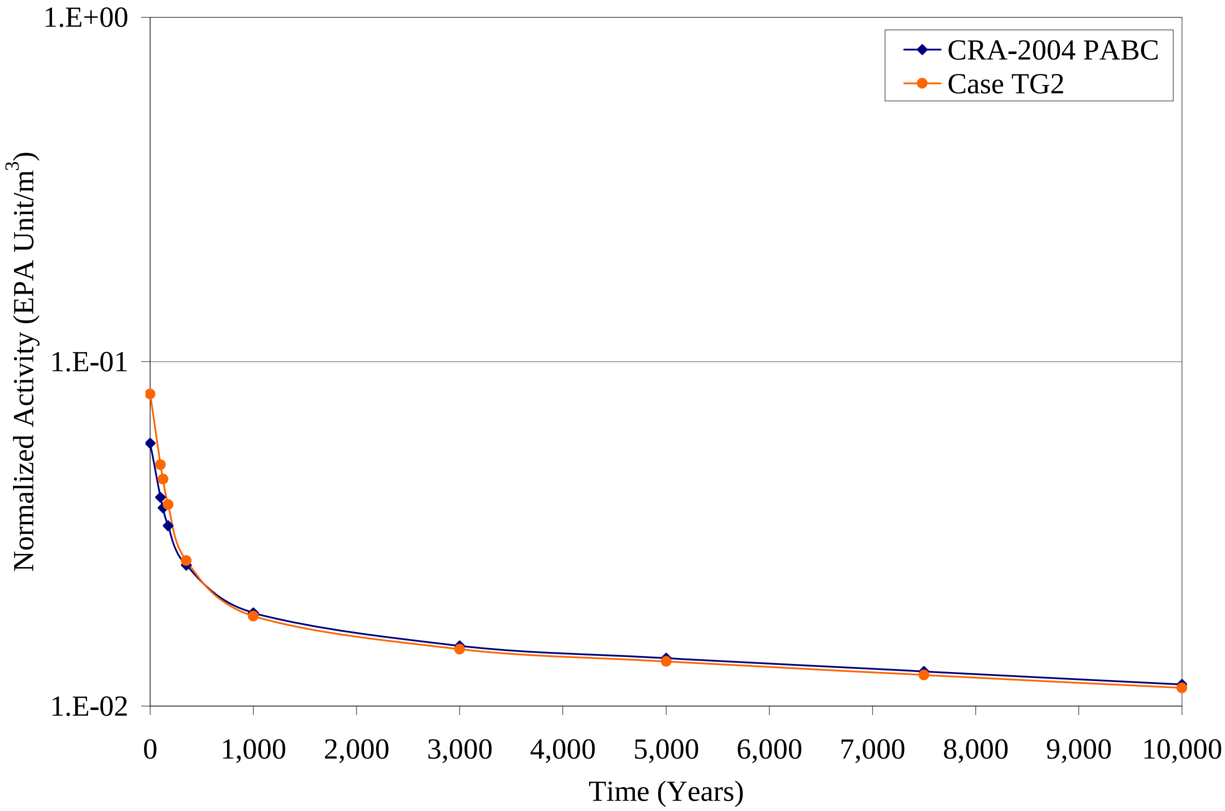


Figure 16. Normalized activity for solid releases as a function of time for Case TG2 compared with the CRA-2004 PABC (Fox 2005).

4.2.2.5 Case TG12 (Group 1 and Group 2 Total)

Adding both the Group 1 and Group 2 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory generally slightly decreased the total radionuclide concentration. The average normalized activity for solid releases as a function of time for Case TG12 compared with the results from the CRA-2004 PABC are shown in Figure 17. At 0 years, the total radionuclide concentration is higher for Case TG12 compared with the CRA-2004 PABC and while after ~600 years, the total radionuclide concentration is lower for Case TG12 versus the CRA-2004 PABC. Case TG12 represents the sum of Cases T and TG2, and so the results are a mix of the results shown for Cases T and TG2.

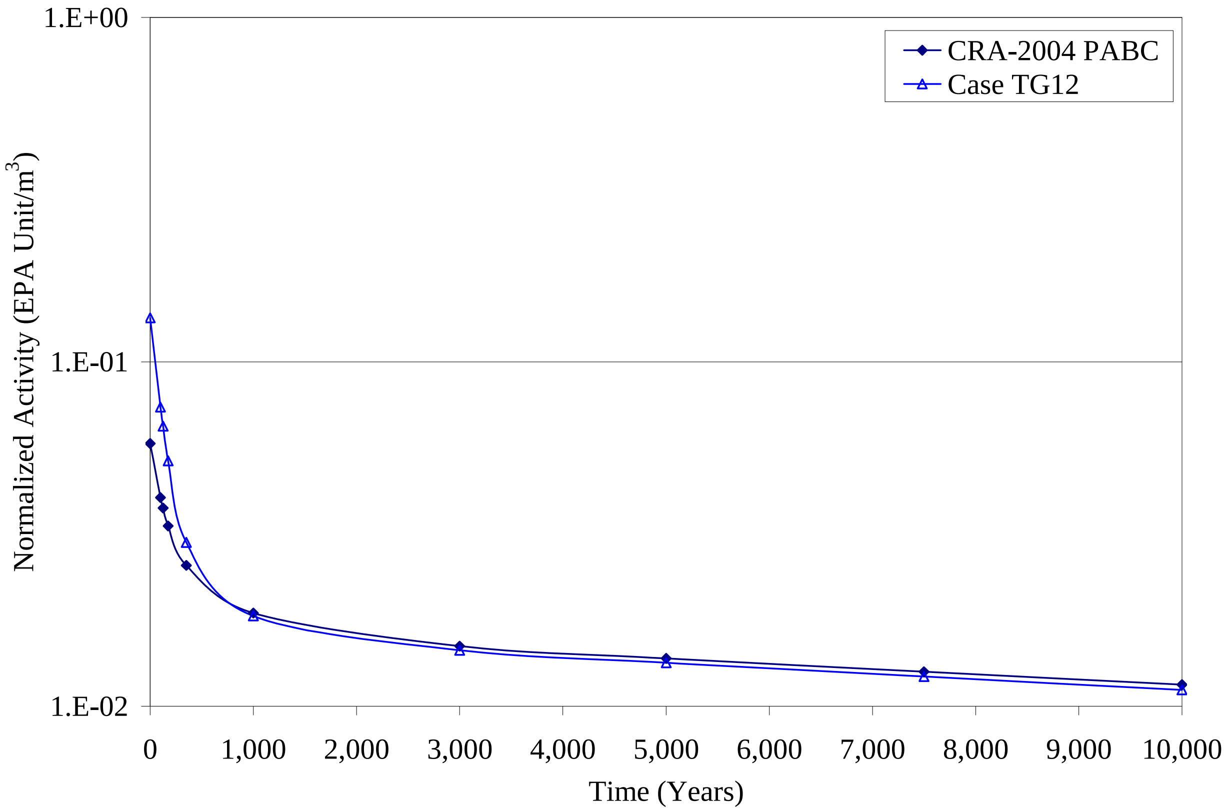


Figure 17. Normalized activity for solid releases as a function of time for Case TG12 compared with the CRA-2004 PABC (Fox 2005).

4.2.2.6 Case 6G3 (GNEP-AFCF)

Adding Group 3 DOE GTCC-like waste stream 6 to the WIPP inventory decreased the total radionuclide concentration. The average normalized activity for solid releases as a function of time for Case 6G3 compared with the results from the CRA-2004 PABC are shown in Figure 18. The normalized activity for Case 6G3 is always lower than the CRA-2004 PABC with the difference increasing until ~1,000 years and then the difference remains fairly constant with time. The decrease in total radionuclide concentration is due mainly to the low concentration of radionuclide per volume in Group 3 waste stream 6.

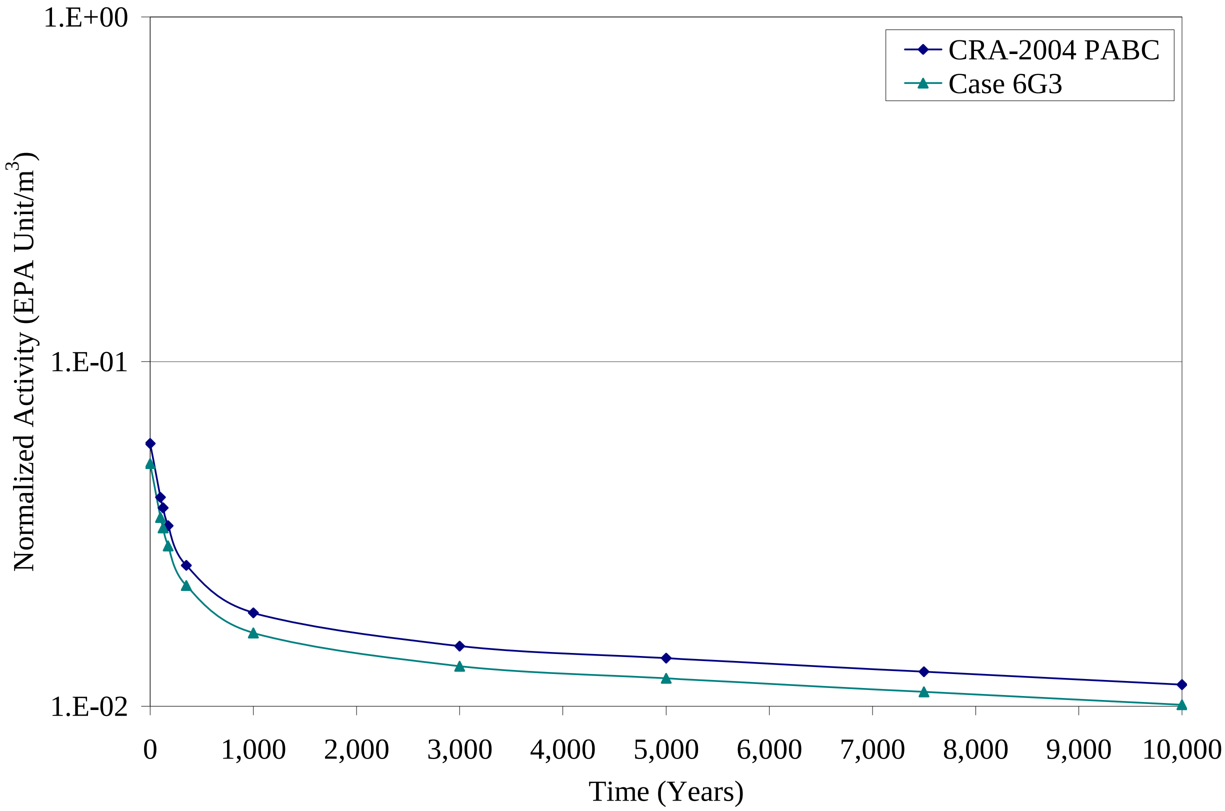


Figure 18. Normalized activity for solid releases as a function of time for Case 6G3 compared with the CRA-2004 PABC (Fox 2005).

4.2.2.7 Case TG123 (Group 1, Group 2 and Group 3 Total)

Adding all the Group 1, Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory generally decreased the total radionuclide concentration. The average normalized activity for solid releases as a function of time for Case TG123 compared with the results from the CRA-2004 PABC are shown in Figure 19. At 0 years, the total radionuclide concentration is higher for Case TG123 compared with the CRA-2004 PABC and while after ~300 years, the total radionuclide concentration is lower for Case TG123 versus the CRA-2004 PABC. Case TG123 represents the sum of Cases T, TG2 and 6G3, and because Case 6G3 dominates the total volume (Table 12), the results are very similar to the results shown for Case 6G3.

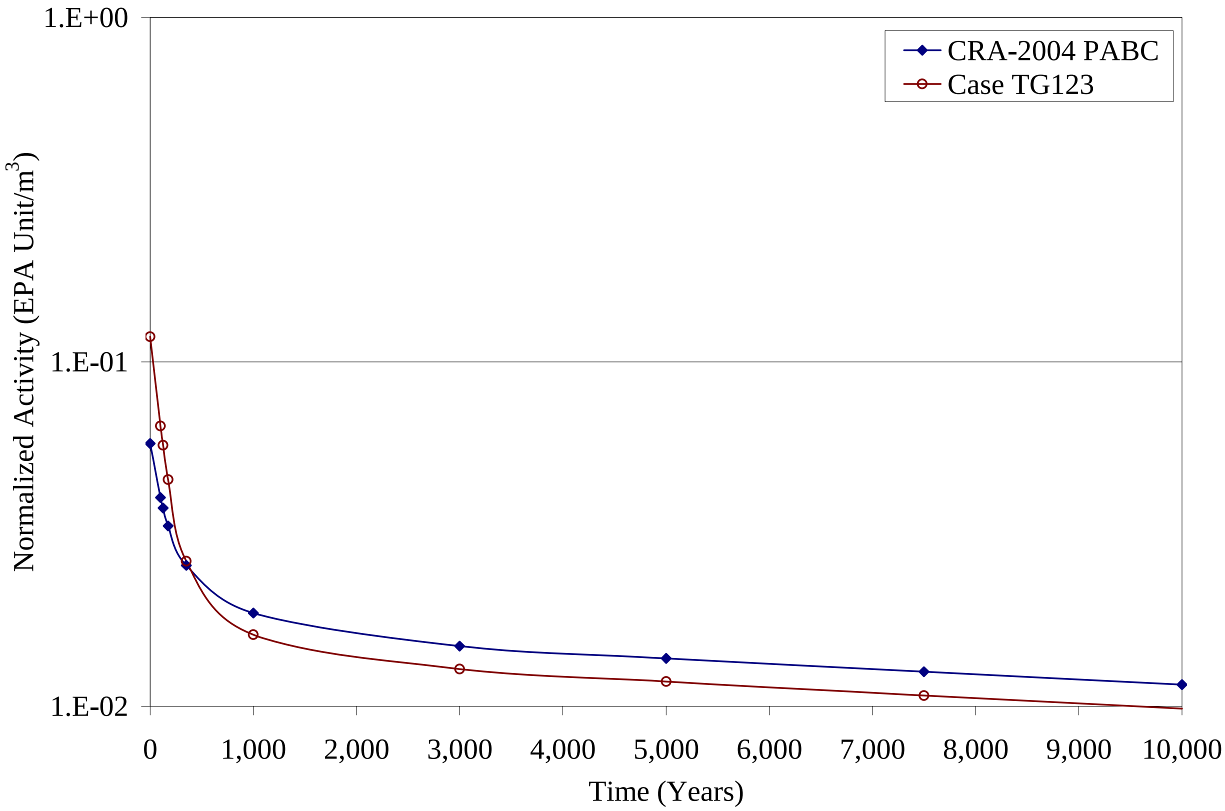


Figure 19. Normalized activity for solid releases as a function of time for Case TG123 compared with the CRA-2004 PABC (Fox 2005).

4.2.3 CCDFGF results

The code CCDFGF assembles the release estimates from all other components of the WIPP PA system to generate cumulative complementary distribution functions (CCDFs) of releases. The CCDFs are then compared with the release limits stated in Section 191.13, less than a 10% chance of a normalized radionuclide release of one unit of waste (f_w) and a less than 0.1% chance of a normalized radionuclide release of ten times the unit of waste (f_w). The values of the mean total normalized release from the CCDFs for each case at the 10% and 0.1% probability are summarized below in Table 14. The incremental changes due to the addition of each waste stream are also shown. As seen in Table 14, the incremental increases in the normalized releases to the IHI from adding the GTCC LLW and DOE GTCC-like waste to the WIPP repository are not substantial enough to jeopardize the WIPP repository compliance with the release limits. The results for each individual case are discussed below.

Table 14. Mean Total Normalized Release at the 10% and 0.1% probability level for each Group 2 and Group 3 case compared the CRA-2004 PABC (Vugrin and Dunagan 2005).

Case	10% probability level	Difference from PABC	0.1% probability level	Difference from PABC
CRA-2004 PABC	0.09	-	0.57	-
Case 4G2	0.10	0.01	0.66	0.09
Case 5G2	0.12	0.04	0.97	0.40
Case 9G2	0.10	0.01	0.70	0.13
Case TG2	0.13	0.04	1.06	0.49
Case TG12	0.23	0.14	2.15	1.58
Case 6G3	0.10	0.01	0.76	0.19
Case TG123	0.27	0.18	2.47	1.91
Max Allowable	1.00		10.00	

4.2.3.1 Case 4G2 (RPS)

Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 4 to the WIPP inventory slightly increased the mean total release CCDF at all probabilities. The mean total release CCDF for Case 4G2 compared with the results from the CRA-2004 PABC are shown in Figure 20. The slight increase is mainly due to the increase in the CH area. As seen in Figure 20, at the 10% probability level, the mean total normalized release increased from 0.09 to 0.10, while at the 0.1% probability level, the mean total normalized release increased from 0.57 to 0.66, which are both well below the release limits.

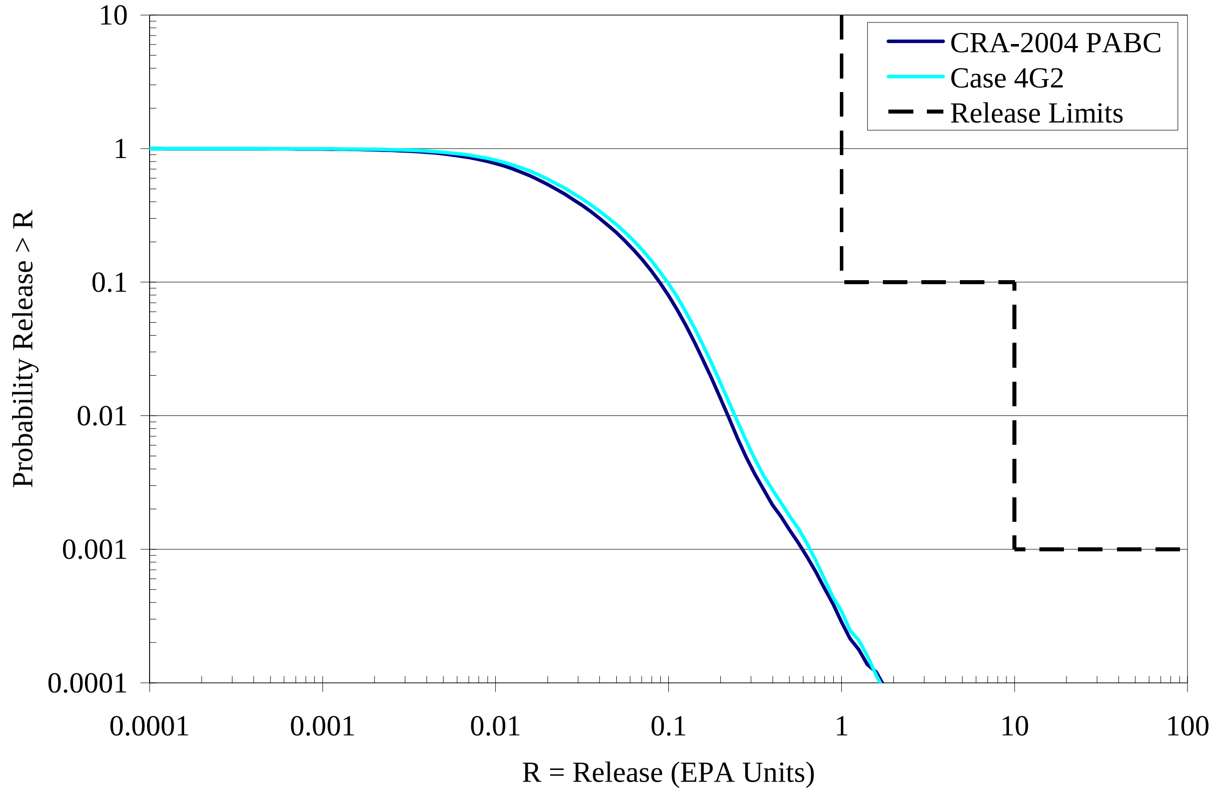


Figure 20. Mean total release CCDF for Case 4G2 compared with the CRA-2004 PABC (Vugrin and Dunagan 2005).

4.2.3.2 Case 5G2 (New Commercial Reactors)

Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 5 to the WIPP inventory increased the mean total release CCDF at all probabilities. The mean total release CCDF for Case 5G2 compared with the results from the CRA-2004 PABC are shown in Figure 21. The increase is mainly due to the increase in the normalized radionuclide concentration for brine release shown in Section 4.2.1.2, while the increase in the CH area contributed as well. As seen in Figure 21, at the 10% probability level, the mean total normalized release increased from 0.09 to 0.12, while at the 0.1% probability level, the mean total normalized release increased from 0.57 to 0.97, which are both well below the release limits.

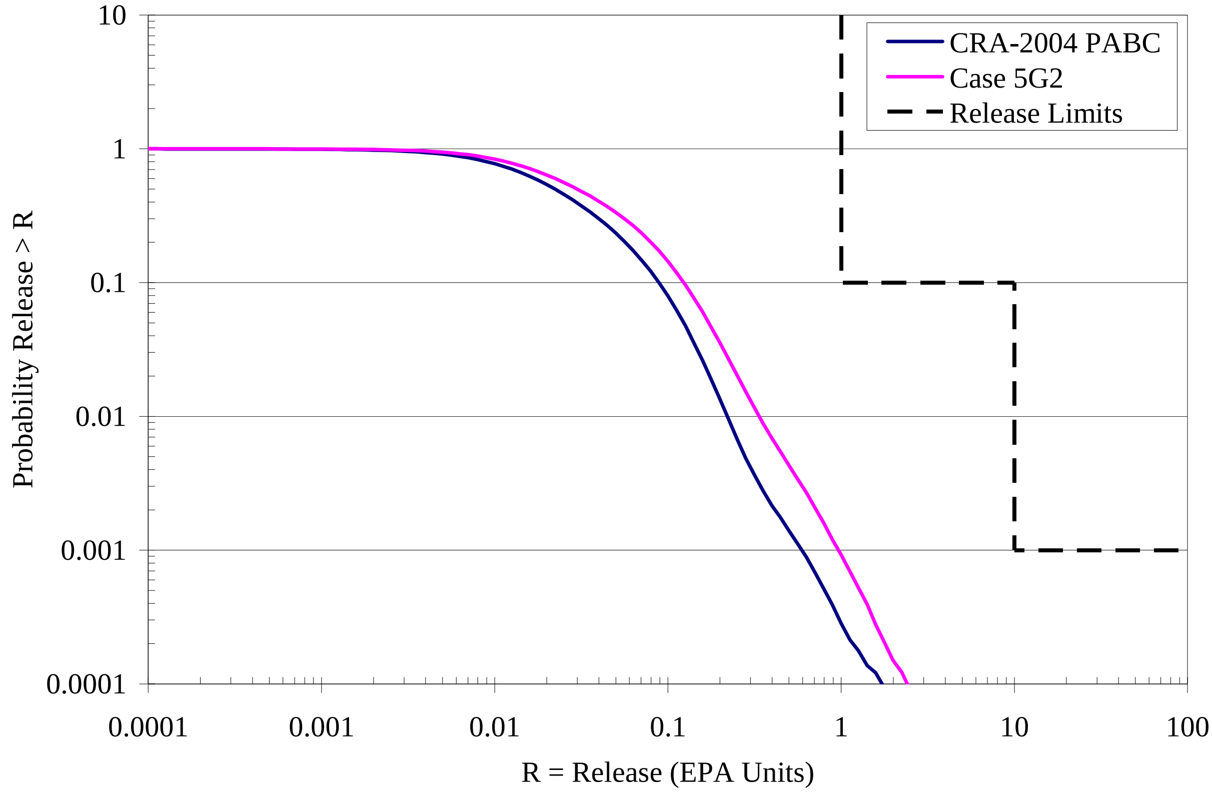


Figure 21. Mean total release CCDF for Case 5G2 compared with the CRA-2004 PABC (Vugrin and Dunagan 2005).

4.2.3.3 Case 9G2 (West Valley NDA/SDA)

Adding Group 2 GTCC LLW and DOE GTCC-like waste stream 9 to the WIPP inventory slightly increased the mean total release CCDF at all probabilities. The mean total release CCDF for Case 9G2 compared with the results from the CRA-2004 PABC are shown in Figure 22. The slight increase is mainly due to the increase in the CH area. As seen in Figure 22, at the 10% probability level, the mean total normalized release increased from 0.09 to 0.10, while at the 0.1% probability level, the mean total normalized release increased from 0.57 to 0.70, which are both well below the release limits.

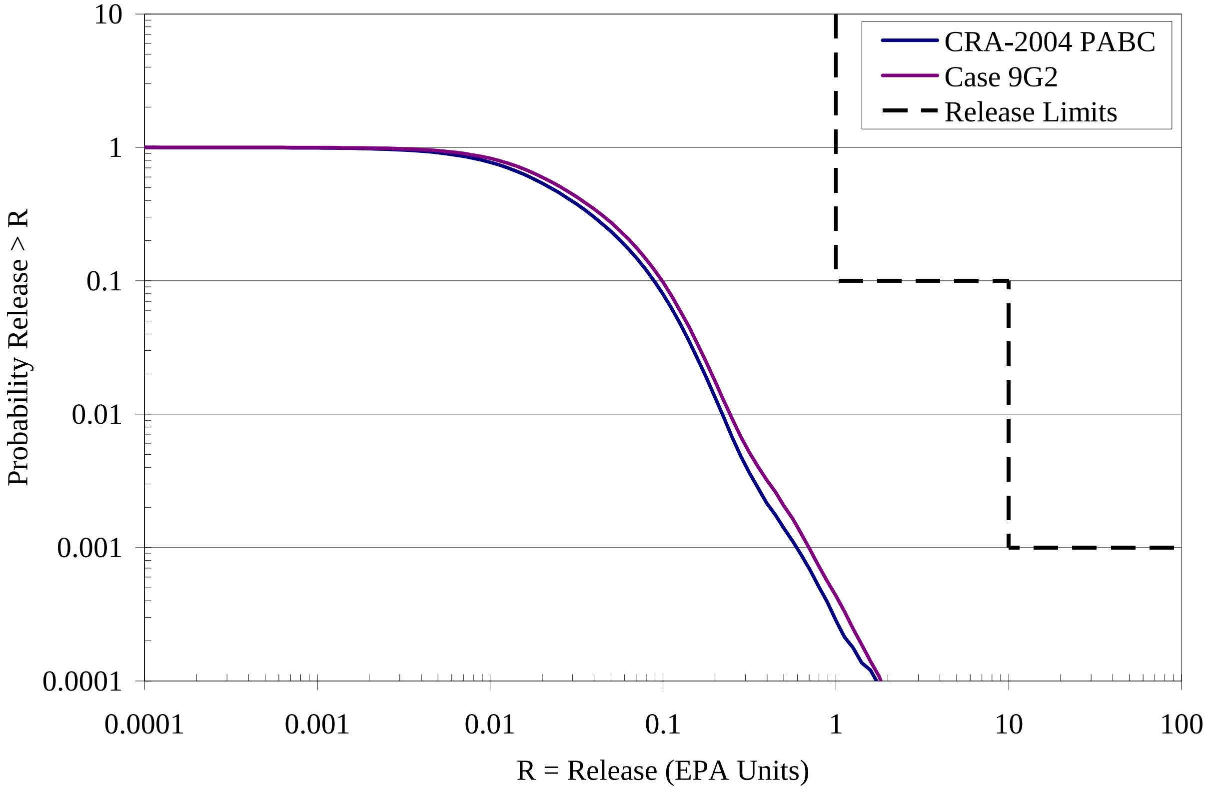


Figure 22. Mean total release CCDF for Case 9G2 compared with the CRA-2004 PABC (Vugrin and Dunagan 2005).

4.2.3.4 Case TG2 (Group 2 Total)

Adding all the Group 2 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory increased the mean total release CCDF at all probabilities. The mean total release CCDF for Case TG2 compared with the results from the CRA-2004 PABC are shown in Figure 23. The increase is due to both the increase in the CH area and the increase in the normalized radionuclide concentration for brine release shown in Section 4.2.1.4. As seen in Figure 23, at the 10% probability level, the mean total normalized release increased from 0.09 to 0.13, while at the 0.1% probability level, the mean total normalized release increased from 0.57 to 1.06, which are both well below the release limits.

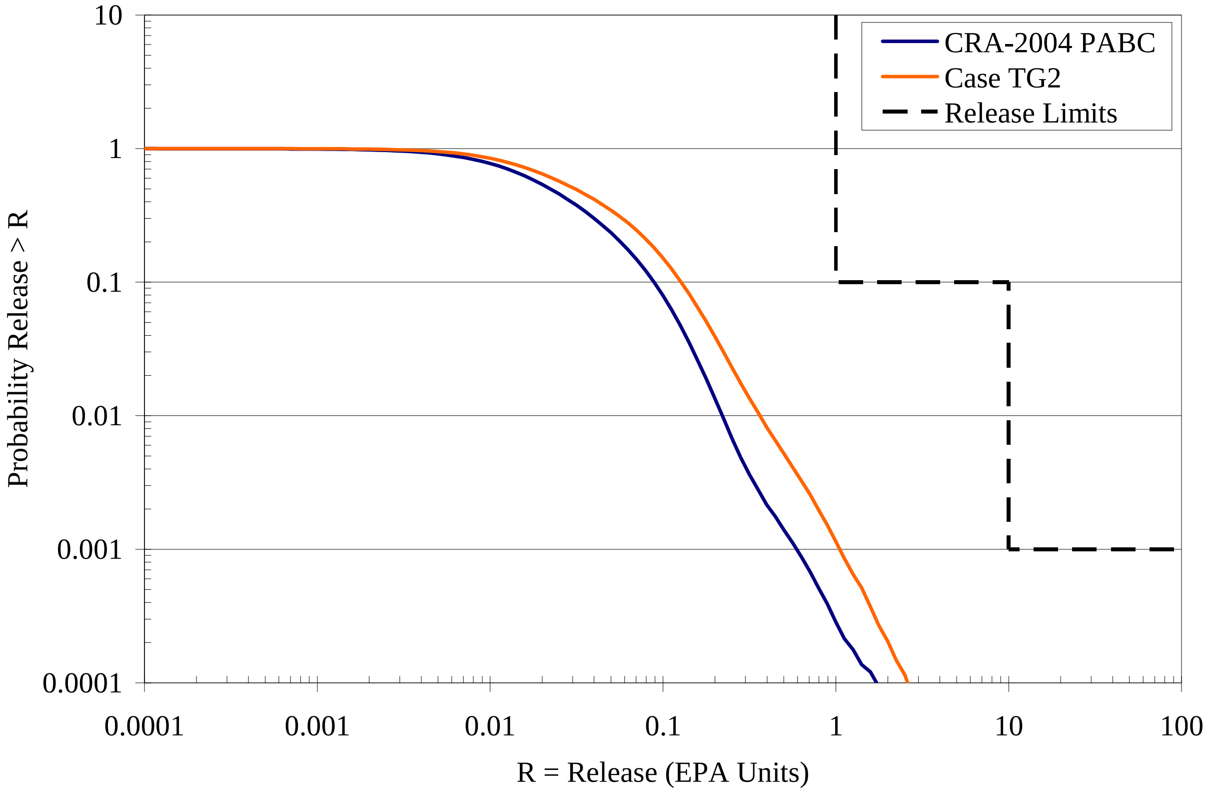


Figure 23. Mean total release CCDF for Case TG2 compared with the CRA-2004 PABC (Vugrin and Dunagan 2005).

4.2.3.5 Case TG12 (Group 1 and Group 2 Total)

Adding both the Group 1 and Group 2 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory increased the mean total release CCDF at all probabilities. The mean total release CCDF for Case TG12 compared with the results from the CRA-2004 PABC are shown in Figure 24. The increase is due to both the increase in the CH area and the increase in the normalized radionuclide concentration for brine release shown in Section 4.2.1.5. As seen in Figure 24, at the 10% probability level, the mean total normalized release increased from 0.09 to 0.23, while at the 0.1% probability level, the mean total normalized release increased from 0.57 to 2.15, which are both well below the release limits.

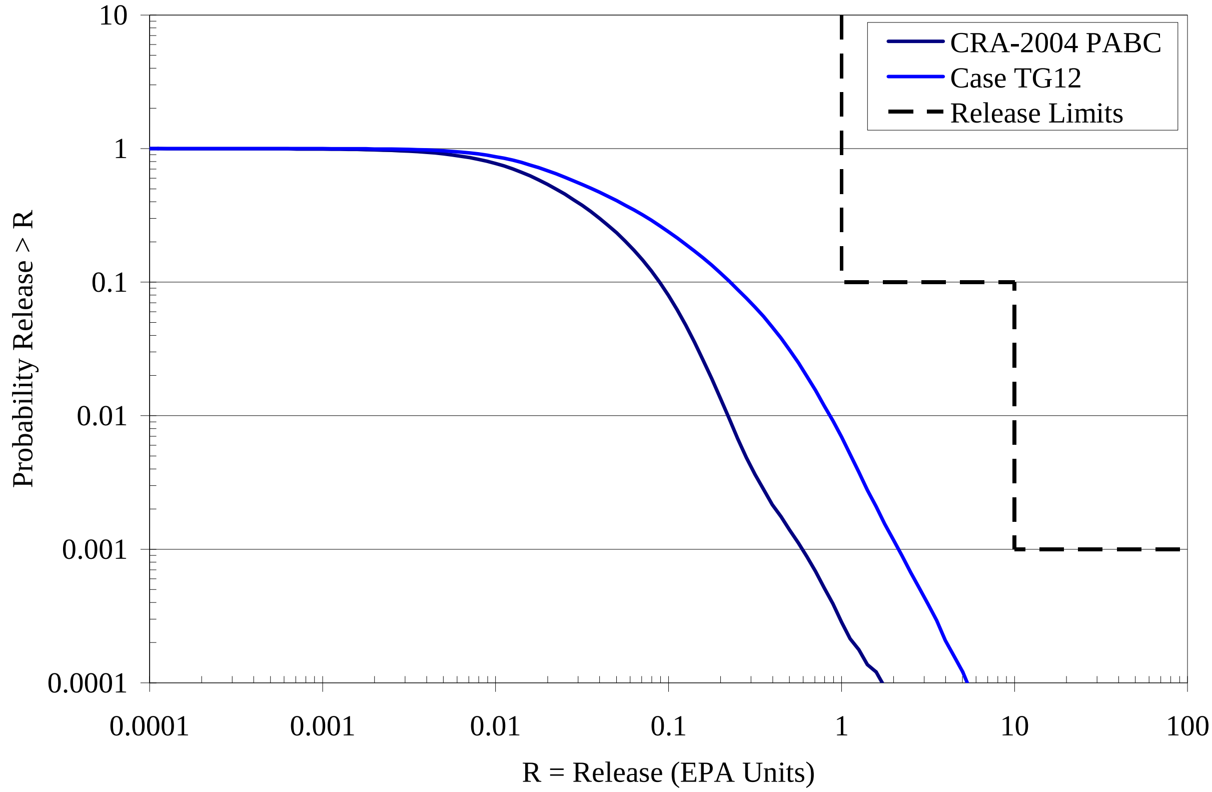


Figure 24. Mean total release CCDF for Case TG12 compared with the CRA-2004 PABC (Vugrin and Dunagan 2005).

4.2.3.6 Case 6G3 (GNEP-AFCF)

Adding Group 3 GTCC LLW and DOE GTCC-like waste stream 6 to the WIPP inventory slightly increased the mean total release CCDF at all probabilities. The mean total release CCDF for Case 6G3 compared with the results from the CRA-2004 PABC are shown in Figure 25. The slight increase is mainly due to the increase in the CH area. As seen in Figure 25, at the 10% probability level, the mean total normalized release increased from 0.09 to 0.10, while at the 0.1% probability level, the mean total normalized release increased from 0.57 to 0.76, which are both well below the release limits.

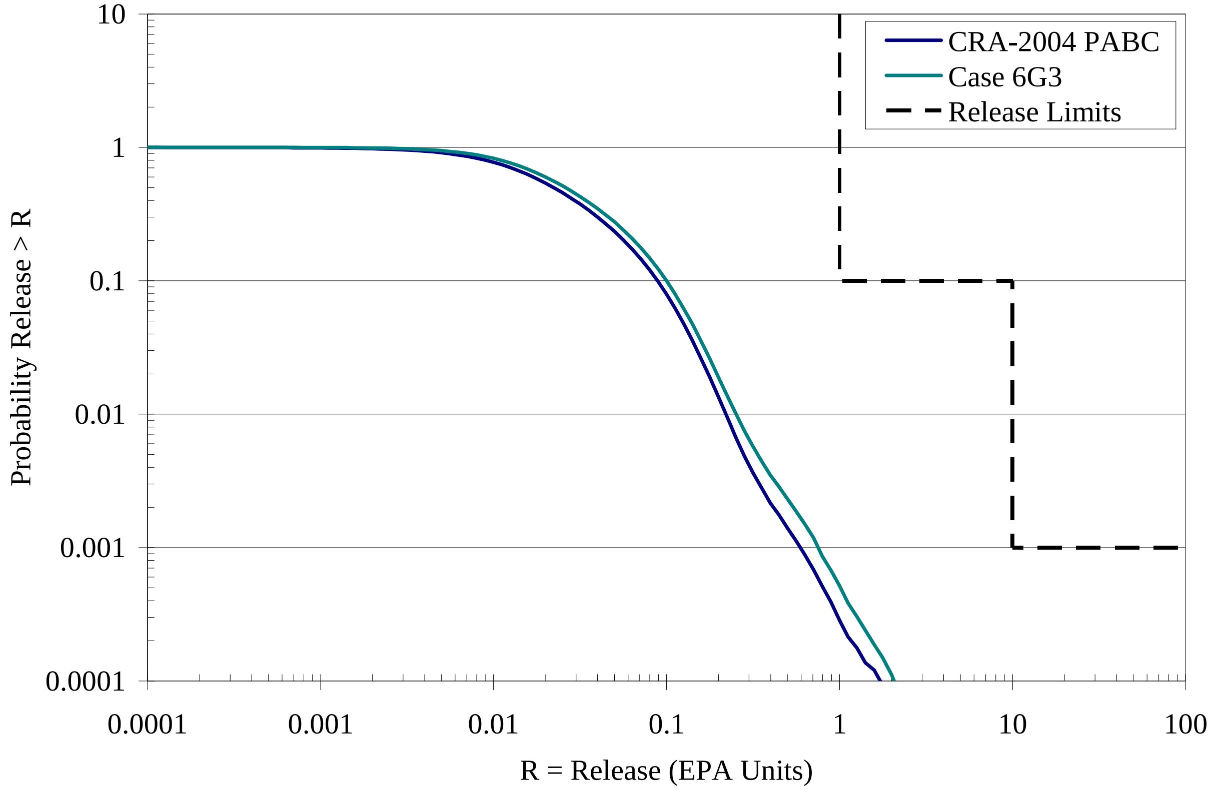


Figure 25. Mean total release CCDF for Case 6G3 compared with the CRA-2004 PABC (Vugrin and Dunagan 2005).

4.2.3.7 Case TG123 (Group 1, Group 2 and Group 3 Total)

Adding all the Group 1, Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste streams to the WIPP inventory increased the mean total release CCDF at all probabilities. The mean total release CCDF for Case TG123 compared with the results from the CRA-2004 PABC are shown in Figure 26. The increase is due to both the increase in the CH area and the increase in the normalized radionuclide concentration for brine release shown in Section 4.2.1.7. As seen in Figure 26, at the 10% probability level, the mean total normalized release increased from 0.09 to 0.27, while at the 0.1% probability level, the mean total normalized release increased from 0.57 to 2.47, which are both well below the release limits.

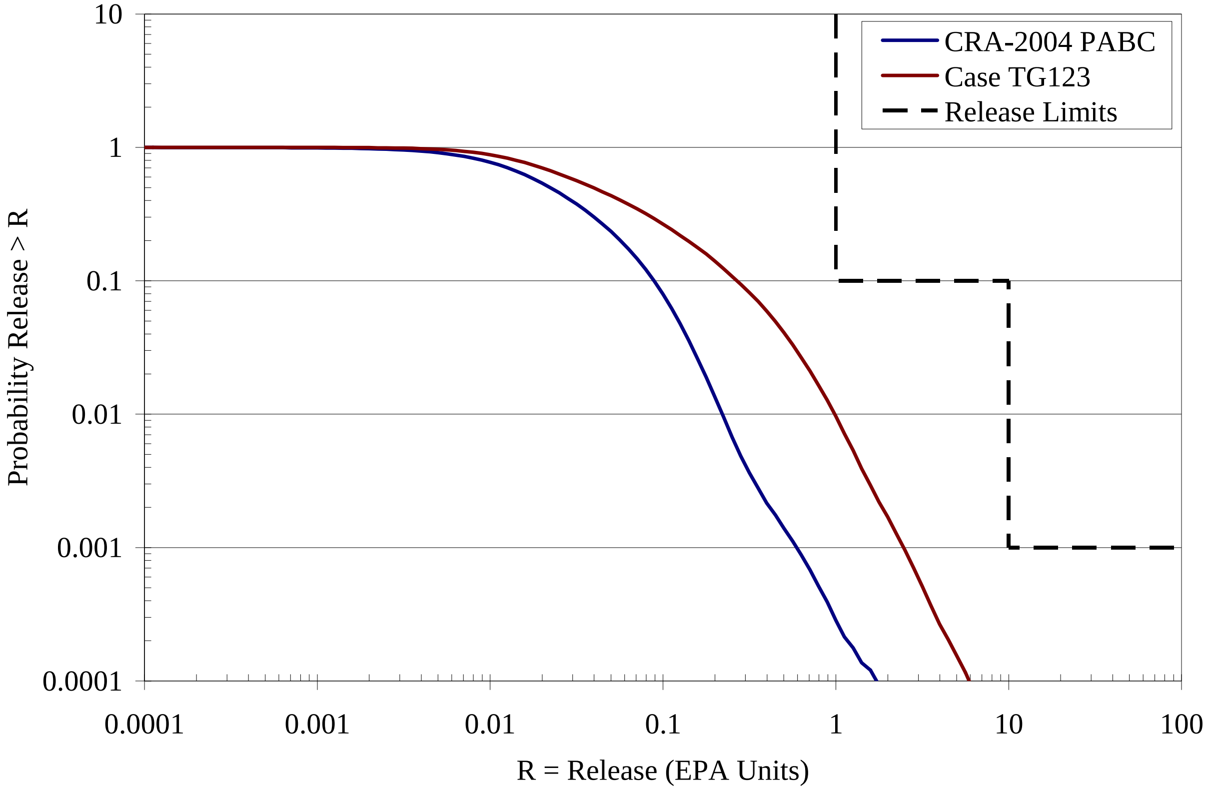


Figure 26. Mean total release CCDF for Case TG123 compared with the CRA-2004 PABC (Vugrin and Dunagan 2005).

4.3 LONG-TERM STABILITY

Long-term stability is also a requirement of the WIPP repository. Analyses of the potential excavation-induced subsidence were conducted and found that it would not be significant due to the depth of the repository and low extraction ratio (U.S. DOE 1996). Furthermore, active institutional controls are to be emplaced such that the repository will not be disturbed for at least 100 years. Therefore, it was determined that there are no long-term stability issues for the WIPP repository. The addition of the Group 2 and Group 3 GTCC LLW and DOE GTCC-like waste will not adversely affect the long-term stability, as the same emplacement strategy is used.

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