

Engineering Design File

NESHAP Modeling for the ICDF Complex

Prepared for:
U.S. Department of Energy
Idaho Operations Office
Idaho Falls, Idaho



Form 412.14
07/24/2001
Rev. 03

1. Title: NESHAP Modeling for the ICDF Complex																			
2. Project File No.:																			
3. Site Area and Building No.:		4. SSC Identification/Equipment Tag No.:																	
<p>5. Summary:</p> <p>Compliance with National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations is an applicable or relevant and appropriate requirement (ARAR) for the INEEL CERCLA Disposal Facility (ICDF) Complex. This Engineering Design File (EDF) presents the modeling methodology employed and the results of that modeling.</p> <p>The Idaho National Engineering and Environmental Laboratory (INEEL) Site boundary was used as the location where the maximally exposed individual (MEI) of the public is located. The radioactive dose from the normal operation of the landfill and the evaporation pond was calculated at this location. The dose was based on the data provided in the "INEEL CERCLA Disposal Facility Design Inventory" (EDF-ER-264).</p> <p>The dose from the landfill operation assumed that the maximum yearly activity entering the landfill would be 36% of the total inventory. The dose from the evaporation pond estimated the radioactivity in the leachate that is discharged into the pond. Leachate activity is maximized by assuming it comes from the full landfill. The remaining particulate radionuclides released used a resuspension factor of 1×10^{-3}. This is the same factor used in 40 CFR 61, Appendix D, for activity in liquids and particulate entering the air.</p> <p>Results of the modeling, as presented below in Table 1, indicate that air emissions from the landfill and the evaporation pond are below levels of concern.</p> <p>Table 1. Estimated dose at the INEEL boundary from the operation of the landfill and evaporation pond.</p> <table border="1" style="width:100%; border-collapse: collapse; margin: 10px 0;"> <thead> <tr> <th style="text-align: center;">Facility</th> <th style="text-align: center;">Dose (mrem/yr)</th> <th colspan="2" style="text-align: center;">Major Radionuclide Contribution to Dose (percentage)</th> </tr> </thead> <tbody> <tr> <td>Landfill operation</td> <td style="text-align: center;">4.59×10^{-2}</td> <td style="text-align: center;">^{129}I -96.6%</td> <td style="text-align: center;">^{137}Cs -1.3%</td> </tr> <tr> <td>Evaporation pond</td> <td style="text-align: center;">5.33×10^{-4}</td> <td style="text-align: center;">^{90}Sr -86.0%</td> <td style="text-align: center;">^{238}Pu -5.8%</td> </tr> <tr> <td>Total dose</td> <td style="text-align: center;">4.64×10^{-2}</td> <td style="text-align: center;">^{129}I -95.5%</td> <td style="text-align: center;">^{137}Cs -1.3%, ^{90}Sr -1.8%</td> </tr> </tbody> </table> <p>Results from this modeling will be used to supply information for the ICDF Landfill and Evaporation Pond Waste Acceptance Criteria.</p>				Facility	Dose (mrem/yr)	Major Radionuclide Contribution to Dose (percentage)		Landfill operation	4.59×10^{-2}	^{129}I -96.6%	^{137}Cs -1.3%	Evaporation pond	5.33×10^{-4}	^{90}Sr -86.0%	^{238}Pu -5.8%	Total dose	4.64×10^{-2}	^{129}I -95.5%	^{137}Cs -1.3%, ^{90}Sr -1.8%
Facility	Dose (mrem/yr)	Major Radionuclide Contribution to Dose (percentage)																	
Landfill operation	4.59×10^{-2}	^{129}I -96.6%	^{137}Cs -1.3%																
Evaporation pond	5.33×10^{-4}	^{90}Sr -86.0%	^{238}Pu -5.8%																
Total dose	4.64×10^{-2}	^{129}I -95.5%	^{137}Cs -1.3%, ^{90}Sr -1.8%																
6. Review (R) and Approval (A) and Acceptance (Ac) Signatures: (See instructions for definitions of terms and significance of signatures.)																			
	R/A	Typed Name/Organization	Signature	Date															
Performer	R	Steven K. Zohner	<i>Steven K. Zohner</i> <i>Danella French per TC</i>	5/10/02															
Checker	R	Same as Independent Peer Reviewer																	
Independent Peer Reviewer	A	Marty Doornbos, Chair, WAG 3 ORB	<i>Marty Doornbos</i>	5/9/02															
Approver	A	Tom Borschel	<i>Tom Borschel</i>	5/9/02															
Requestor	Ac	Don Vernon	<i>D. Vernon</i>	5/9/02															
Point of Contact		Pam French	<i>Danella French</i>	5/9/02															
7. Distribution: (Name and Mail Stop)																			

CONTENTS

ACRONYMS.....	v
1. SUMMARY	1
2. KEY ASSUMPTIONS	3
3. INEEL CERCLA DISPOSAL FACILITY (ICDF) LANDFILL ACTIVITY, EMISSIONS, AND DOSE CALCULATIONS	6
4. EVAPORATION POND ESTIMATED SOURCE TERM AND DOSE CALCULATIONS.....	13
4.1 Calculating Radioactivity in the Leachate	14
4.2 Generalized Spreadsheet Calculations to Determine Radioactivity in Leachate	15
5. CONCLUSION	27
6. REFERENCES	29
Appendix A—NESHAP Evaluation	
Appendix B—Unit Dose Calculations	
Appendix C— K_d Values	

FIGURES

1. Location of 2000 MEI in relation to the INEEL and the ICDF Complex	12
---	----

TABLES

1. Estimated dose at the INEEL boundary from the operation of the landfill and evaporation pond.....	1
2. Schedule of anticipated volume entering the landfill	6
3. Full landfill air emissions and dose to the MEI at the INEEL boundary.....	8
4. Verification for spreadsheet calculations determining leachate activity	17
5. Full landfill, leachate radioactivity based on radioactive inventory and K_d values.....	18
6. Well water volumes, radioactive sources, and estimated doses at the INEEL boundary (DOE-ID 1997)	23
7. Total dose from the evaporation pond (combined leachate and well water)	23
8. Estimated dose at the INEEL boundary from the operation of the landfill and evaporation pond.....	28

ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CWID	CERCLA Waste Inventory Database
D&D&D	deactivation, decontamination, and decommissioning
DOE-ID	Department of Energy Idaho Operations Office
ICDF	INEEL CERCLA Disposal Facility
IDW	investigation-derived waste
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
MEI	maximally exposed individual
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
OU	operable unit
SRPA	Snake River Plain Aquifer
SSSTF	Staging, Storage, Sizing, and Treatment Facility
WAC	Waste Acceptance Criteria

NESHAP Modeling for the ICDF Complex

1. SUMMARY

The Idaho National Engineering and Environmental Laboratory (INEEL) Site boundary was used as the location where the maximally exposed individual (MEI) of the public is located. The radioactive dose from the normal operation of the landfill and the evaporation pond was calculated to this location. The dose was based on the data provided in the INEEL CERCLA Disposal Facility (ICDF) Design Inventory (EDF-ER-264).

As provided in 40 CFR 61, Appendix D, an initial screening was done to determine if the ICDF Complex required National Emissions Standards for Hazardous Air Pollutants (NESHAP) modeling (see Appendix A). This screening indicated that both the landfill and the evaporation pond exceeded Appendix D levels and required modeling.

The dose from the landfill operation assumed that the maximum yearly activity entering the landfill would be 36% of the total (EDF-1547). The only mitigation for landfill activities was a resuspension factor for soil of 1×10^{-6} (McKenzie-Carter et al. 1999; Brodsky 1980; Healy 1982). These assumptions present the worst-case scenario based on this modeling approach. Additional reduction factors may include wetting the soil as it is unloaded, maintaining moist soil as it is moved to its correct location/slope, applying a dust suppressant daily, and using the actual exposed surface area for potential emissions.

Results of the modeling, as presented below in Table 1, indicate that air emissions from the landfill and the evaporation pond are below levels of concern.

Table 1. Estimated dose at the INEEL boundary from the operation of the landfill and evaporation pond.

Facility	Dose (mrem/yr)	Major Radionuclide Contribution to Dose (percentage)
Landfill operation	4.59×10^{-2}	^{129}I – 96.6%, ^{137}Cs – 1.3%
Evaporation pond	5.33×10^{-4}	^{90}Sr – 86.0%, ^{238}Pu – 5.8%
Total dose	4.64×10^{-2}	^{129}I – 95.5%, ^{137}Cs – 1.3%, ^{90}Sr – 1.8%

Results from this modeling will be used to supply information for the ICDF landfill and evaporation pond Waste Acceptance Criteria (WAC).

The dose from the evaporation pond was based on the estimated radioactivity in the landfill that is transferred to the pond as leachate. Leachate activity is maximized by assuming it comes from the full landfill. This assumption estimates the maximum yearly dose when the landfill is full and without a cap. All of the ^3H , ^{85}Kr , and ^{129}I in the landfill and pond was assumed to be released. The remaining particulate radionuclides released in the evaporation pond used a resuspension factor of 1×10^{-3} . This is the same factor used in 40 CFR 61, Appendix D, for activity in liquids entering the air. The modeling results will supply information for the ICDF landfill and evaporation pond WAC(s).

The Staging, Storage, Sizing, and Treatment Facility (SSSTF) was evaluated using 40 CFR 61.96 to determine if an application for approval to construct was required. The source term was derived using 40 CFR 61 Appendix D. This source term was modeled and the effective dose equivalent was significantly less than 0.1 mrem/yr. Since it was less than 0.1 mrem/yr, no application is required. The potential to emit was also calculated and the dose was again less than 0.1 mrem/yr. This means that no monitoring of the SSSTF stack is required. Appendix A contains the SSSTF evaluation.

2. KEY ASSUMPTIONS

Key assumptions used for dose determination are listed and discussed below. Since the well water contains such low levels of radioactivity, it was easiest just to assume that all the water went to the evaporation pond in a single year. This assumption had no effect on the total dose and greatly simplified calculations.

The factor used for the landfill is another case where a single factor is used to estimate emissions from multiple processes. Emission ranged from activities that would emit very little activity (10^{-8}) to processes that would emit larger amounts (10^{-4} to 10^{-5}). The selected emission factor (10^{-6}) for the landfill is the best overall estimate (McKenzie-Carter et al. 1999; Brodsky 1980; Healy 1982).

Landfill

- The maximum annual landfill delivery would be 36% of the total.
- Maximum yearly radioactivity receipts would be 36% of the total activity.
- All radioactivity in the 36% maximum is assumed to be exposed and the 1×10^{-6} emission factor is applied to the total radioactivity delivered in the maximum year.
- All of the gaseous radionuclides (^3H , ^{85}Kr , ^{129}I) are assumed to be released.
- The assumed density of the soil is 95 lb/ft³ (Perry 1995).

Landfill Leachate Going to the Evaporation Pond

- It is assumed that the landfill is full (510,000 yd³) and all the radioactivity is available for leaching (EDF-1540).
- The annual volume of liquid available for leaching is 857,234 gal/yr (EDF-ER-269, Tables 3-1 and 3-2).
- Leachate concentrations were based on information in EDF-ER-269.
- No gaseous radionuclides would be available for leaching, since they are all assumed to be released from the landfill.

Well Water Going to the Evaporation Pond

- The dose was calculated assuming all well water went to the evaporation pond in 1 year:
 - Perched—30,000 gal
 - Snake River Plain Aquifer (SRPA) (Group 5)—264,000 gal
 - Operable Unit (OU) 3-14—36,000 gal
 - Total best estimate 330,000 gal.

- The maximum radionuclide concentrations (DOE-ID 1997) were identified from samples of perched water and SRPA samples. These maximum concentrations were then used to calculate the activity in all perched water and SRPA water. The OU 3-14 used the same maximum concentrations as the SRPA.
- Emission calculations assumed 1×10^{-3} of the radioactivity in the water became airborne. Gaseous radionuclides from the well water (^3H , ^{85}Kr , ^{129}I) were assumed to all be released at the evaporation pond in this 1 year.

Evaporation Pond

- It is assumed that 1×10^{-3} of the activity entering the pond will be released to the atmosphere.
- Gaseous radionuclides from wells are assumed to all be released at the evaporation pond.

Since there is very little radioactivity in the well water, the maximum concentration of each radionuclide found in the perched water was used to calculate the total perched water radioactivity. The maximum radioactivity for each radionuclide in the SRPA was used to calculate the total radioactivity in the aquifer. Finally, the dose from the evaporation pond was calculated with the assumption that all the well water went to the pond in 1 year (see Appendix A).

Landfill Resuspension Factor

The maximum waste volume arriving at the landfill in any 1 year is estimated at 36% of the total. The estimated dose from the landfill operation is based on this year as the worst case. It was also assumed that 36% of the total radioactivity goes to the landfill in this 1 year.

Based on technical discussions and a literature search, the following resuspension factors were determined to be most representative for the ICDP Complex. The preliminary modeling used 1×10^{-6} resuspension factor. This was applied to the total quantity of radioactivity entering the landfill during the maximum loading of 36% in 1 year. A review of the sources for resuspension factors reaffirmed its usefulness. At present, the exact operation of the landfill is not specific enough to allow each operational step to be evaluated and a more precise resuspension factor determined. The use of 1×10^{-6} appears to be a good estimate for what quantities may contribute to dose at the INEEL boundary.

The following are some quotes from Brodsky (1980) discussing the 10^{-6} factor:

“Stewart carried out experiments outdoors and recommended a factor of 10^{-6} as an appropriate average value for use in hazard evaluation both in the laboratory and in the field.”

“...the long term applicability of 10^{-6} as a general resuspension factor having a reasonable factor of safety for hazard evaluation and design purposes.”

“...the ‘real-world’ values generally range between 10^{-6} and 10^{-9} . Thus, as indicated by a number of the authors cited, 10^{-6} would generally be a safe value for planning and design of facilities and procedures for radiation protection purposes, for either rough or smooth surfaces.”

“However, Franke have found from data collected in their survey that usually no more that 10^{-6} of the material in process will enter the body of a worker in the event of a release caused by an explosion or other dispersing incident. Even for

volatile materials at elevated temperatures, no more than 10^{-5} of the material in process entered the body after release. In several accident cases involving Pu, Am and Ir, which the author evaluated at the University of Pittsburgh whole body counter, estimated fractional intakes of material in process were 10^{-6} or less, even for workers handling material at arms' length at the time of accident."

"It would also appear safe to use 10^{-6} as a reasonable conservative generic estimate of the maximum fractional amount of plant throughput that gets into one employee via inhalation."

"Conclusion

...the following probabilities (or fractional amounts) may be assumed to usually remain $< 10^{-6}$:

- (a) The fractional amount of material handled that is inhaled by a worker in an accident or explosion.
- (b) The fractional amount of radioactivity placed into process in routine operations that will enter the body of any worker, averaged over an extended period (e.g., 1 yr).
- (c) The fractional amount of contamination on 1 m^2 of floor or ground that will enter 1 m^3 of air and be respirable by any person (over an extended period of time) either outdoors within large contaminated areas, or indoors with smaller contaminated areas.

Usually the above fractions will be much less than 10^{-6} ."

The following are some quotes from Healy (1982) that also discusses the 10^{-6} factor.

"...the values for mechanical disturbance range from about 2×10^{-6} to $7 \times 10^{-5} \text{ m}^{-1}$ For periods of no activity, with relatively fresh deposited material, the values generally range from 10^{-8} to $2 \times 10^{-6} \text{ m}^{-1}$."

"Resuspension rates from agriculture operations:

Disking — 4×10^{-8}

Subsoiling — 7×10^{-7} to 3×10^{-8}

Planting — 1×10^{-6} to 6×10^{-7} ."

3. INEEL CERCLA DISPOSAL FACILITY (ICDF) LANDFILL ACTIVITY, EMISSIONS, AND DOSE CALCULATIONS

The landfill will be the disposal facility for Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) contaminated soils and other generated waste. All of the contaminated soil will go to the landfill without treatment. The schedule for landfill operations came from EDF-1547 and is provided in Table 2.

The total landfill volume is 510,000 yd³ (DOE-ID 1999). The anticipated maximum volume, from EDF-1540, including deactivation, decontamination, and decommissioning (D&D&D) and investigation-derived waste, (IDW) waste, is 483,647 yd³ (369,775 m³). The maximum yearly volume of 36%, as shown in Table 2, was used in emission calculations. The volume estimates presented in Table 2 are derived from annual soil projections (without D&D&D) in Table 6-1 of the CERCLA Waste Inventory Database (CWID) Report (DOE-ID 2000). The maximum yearly volume of 36% depicts the worst-case scenario for any 1 year, and therefore errs on the conservative side.

Table 2. Schedule of anticipated volume entering the landfill.

Year	Volume from CWID (m3)	Volume (yd3)	1.24 Scaled Volume (yd3)	% of Total Volume
2003	32,342	42,302	52,257	10
2004	102,317	133,826	165,320	32
2005	112,317	146,905	181,477	36
2006	46,613	60,968	75,315	15
2007	7,084	9,266	11,446	2
2008	14,968	19,577	24,185	5
Total	315,641	412,844	510,000	100

The total volume currently slated for landfill disposal (excluding D&D&D and IDW waste) is 412,843 yd³. Evaluation of the risk posed by a full landfill is a scope of this report. In order to accomplish this, it is assumed that the composition of the additional 97,157 yd³ of waste (510,000 – 412,843 yd³) is similar to the composition of waste slated for disposal at the landfill. A multiplier is applied to the volume of each annual amount of waste in Table 2, in order to adjust the volume to reflect a full landfill. This same multiplier is applied to the landfill activity and leachate activity in Tables 3 and 7, respectively. The multiplier is simply the landfill capacity (510,000 yd³) divided by the total volume of waste slated for disposal (412,843 yd³). This multiplier equals 1.23533.

The radioactivity entering the landfill is shown in Table 3. This table was calculated based on the dose for the year when the maximum amount of volume goes to the landfill, which is 36%. It was assumed that 36% of the entire radioactivity went to the landfill within the 36% of the volume.

The contaminated soil will be unloaded at the landfill. A resuspension factor of 1×10^{-6} was used to estimate the amount of activity that would become airborne. This resuspension value was derived from available literature values (McKenzie-Carter et al. 1999; Brodsky 1980; Healy 1982). The factor is applied to the total radioactivity in the soil and not just the activity exposed on the surface.

No other reduction factors were used in the landfill operations. Reduction factors that include daily application of dust suppression, operational restriction such as reduction of the number of shifts that may be worked, and reduced and/or stopped winter operation were not considered. Other operational conditions may include minimization of the contaminated soil surface area.

The current design inventory lists a greater number of radionuclides than is noted in Table 3. The CWID Report radionuclide list was truncated using three screening criteria listed below:

1. Activity values were significantly small. Sixty-eight radionuclides with activities less than or equal to 1×10^{-16} generated an insignificant amount of decay (120 decays per year) and were removed from the list of radionuclides used in the unit dose calculations. A list of the removed radionuclides from the largest activity (3×10^{-16} Ci) to the smallest activity (0 Ci) is listed below:

Activity $\leq 1 \times 10^{-16}$

Xe-133, Xe-129m, U-237, U-230, Tb-161, Sn-125, Sn-117m, Rb-86, Pr-143, Nd-147, La-138, In-115m, I-131, Eu-156, Er-169, Cs-136, Cs-132, Ce-142, Bi-213, Ba-140, Ba-136m, Am-245, Ag-111, Ag-106, Th-226, Ra-222, Rn-218, Xe-131m, La-140, Cm-241, Xe-127, Ce-141, Te-129, Te-129m, Pm-148, Pu-237, Rh-103m, Pm-148m, In-114, In-114m, Cr-51, Cd-115m, Sr-89, Sb-124, Y-91, Nb-95m, Fe-59, Tb-160, Tm-170, Bk-250, Pu-246, Am-246, Cm-250, Te-123m, Bk-249, Cf-252, Sc-46, Te-127, Te-127m, Nb-92, Cf-251, Cm-242, Sn-123, Cm-248, Cf-250, Cf-249, Pu-243, Cm-247.

2. Nineteen radionuclides listed in the design inventory were not located within the CAP-88 database. An alphabetical list of the radionuclides removed from consideration in the unit dose calculations is provided below:

Not Found In CAP-88 Database

Ag-108, Ag-108m, Cd-109, Eu-150, Gd-153, Kr-81, Nd-144, Np-235, Np-236, Pm-146, Rh-102, Sm-146, Sm-148, Sm-149, Sn-119m, Sn-121m, Tc-98, Te-123, Tm-171.

3. There were 31 daughter products (5 daughters and 26 radon daughters) of the parent radionuclides located on the unit dose calculation list. The activities of these daughter products were included in the unit dose calculations of the parent radionuclide and therefore were not required. An alphabetical list of the daughter and radon daughter products is provided below:

Daughters

Ba-137m, Pr-144m, Te-125m, Y-90, Rh-106

Radon daughters

Bi-210, Bi-211, Bi-212, Bi-214, Fr-223, Pa-231, Pb-209, Pb-210, Pb-211, Pb-212, Pb-214, Po-210, Po-211, Po-212, Po-213, Po-214, Po-215, Po-216, Po-218, Ra-224, Rn-219, Rn-220, Rn-222, Tl-207, Tl-208, Tl-209.

The unit curie dose calculations were modeled with the CAP-88 dispersion/dose code (Beres 1990), assuming ground-level release and using a 10-year average meteorology from 10-m level of National Oceanic and Atmospheric Administration's (NOAA) Grid 3 tower. For purposes of NESHAP, multiple-year average meteorology is used. The latest long-term average wind files from NOAA are

10-year averages from 1987 through 1996. The NOAA-provided 10-year average annual rainfall is 20.8 cm and the temperature is 279 K (6°C) (INEEL 1998).

For permitting purposes it has been decided that the MEI receptor will be located on the INEEL boundary rather than at the location determined for the annual NESHAP report (INEEL 1998). This is because the actual MEI has the potential to be different from year to year. The worst-case MEI at the Site boundary will bound any actual location.

The MEI location is determined by screening calculations using CAP-88. Doses are calculated for INEEL boundary locations that are closest within each of the 16 compass direction sectors. For facilities on the south end of the INEEL, the MEI is within the south-southwest (SSW) sector. This is because the predominate nocturnal air movement is from the north-northeast (NNE) and these facilities are much closer to the southern INEEL boundary.

The landfill was modeled as an area source (470 ft by 470 ft) and 13,160 m to the SSW. The evaporation pond was modeled as an area source (150 ft by 300 ft) and 13,069 m to the SSW boundary. It was determined that the unit curie dose to the boundary was the same for a point source or an area source due to the source's distance to the boundary (INEEL 1998).

Figure 1 depicts the location of the 2000 INEEL MEI in relation to the INEEL boundary and the ICDF Complex. The dose calculations are included in Appendix B.

Table 3 summarizes the landfill emissions for the maximum yearly volume and uses the 1×10^{-6} resuspension factor. The calculated dose is to the MEI at the INEEL boundary.

Table 3. Full landfill air emissions and dose to the MEI at the INEEL boundary.

Radioactive Source	Total Landfill Activity (Ci)	Maximum Yearly Input 36% (Ci)	Scaling Factor 1.24 (Ci)	1E-06 Resuspension Factor (Ci)	Unit Dose (mrem/Ci)	MEI Dose at Boundary (mrem)	Major Radionuclides Percent Contribution to Dose (% of mrem)
Ac-225	2.4E-08	8.7E-09	1.1E-08	1.1E-14	9.98E-02	1.10E-15	—
Ac-227	9.7E-06	3.5E-06	4.3E-06	4.3E-12	1.07E+01	4.60E-11	—
Ac-228	7.2E-11	2.6E-11	3.2E-11	3.2E-17	2.00E-01	6.40E-18	—
Ag-109m	2.3E-12	8.4E-13	1.0E-12	1.0E-18	1.38E-25	1.38E-43	—
Ag-110	2.5E-11	8.8E-12	1.1E-11	1.1E-17	6.35E-35	6.99E-52	—
Ag-110m	2.6E-09	9.5E-10	1.2E-09	1.2E-15	2.24E-02	2.69E-17	—
Am-241	1.1E+01	4.1E+00	5.0E+00	5.0E-06	9.18E+00	4.59E-05	0.100
Am-242	2.1E-05	7.7E-06	9.6E-06	9.6E-12	8.67E-04	8.32E-15	—
Am-242m	2.1E-05	7.7E-06	9.6E-06	9.6E-12	8.85E+00	8.50E-11	—
Am-243	1.6E-04	5.7E-05	7.1E-05	7.1E-11	9.18E+00	6.52E-10	—
At-217	2.4E-08	8.7E-09	1.1E-08	1.1E-14	0.0E+00	0.0E+00	—
Be-10	5.4E-07	1.9E-07	2.4E-07	2.4E-13	0.0E+00	0.0E+00	—
C-14	2.2E-05	7.9E-06	9.7E-06	9.7E-12	1.23E-03	1.19E-14	—
Cd-113m	7.7E-01	2.8E-01	3.4E-01	3.4E-07	0.0E+00	0.0E+00	—

Table 3. (continued).

Radioactive Source	Total Landfill Activity (Ci)	Maximum Yearly Input 36% (Ci)	Scaling Factor 1.24 (Ci)	1E-06 Resuspension Factor (Ci)	Unit Dose (mrem/Ci)	MEI Dose at Boundary (mrem)	Major Radionuclides Percent Contribution to Dose (% of mrem)
Ce-144	8.6E-04	3.1E-04	3.8E-04	3.8E-10	8.89E-03	3.38E-12	—
Cm-243	1.7E-06	6.1E-07	7.5E-07	7.5E-13	6.15E+00	4.61E-12	—
Cm-244	8.5E-04	3.1E-04	3.8E-04	3.8E-10	4.85E+00	1.84E-09	—
Cm-245	3.8E-08	1.4E-08	1.7E-08	1.7E-14	9.49E+00	1.61E-13	—
Cm-246	8.5E-10	3.1E-10	3.8E-10	3.8E-16	9.38E+00	3.56E-15	—
Co-57	1.7E-03	6.3E-04	7.8E-04	7.8E-10	1.46E-03	1.14E-12	—
Co-58	2.8E-17	1.0E-17	1.2E-17	1.2E-23	2.67E-03	3.20E-26	—
Co-60	9.2E+01	3.3E+01	4.1E+01	4.1E-05	1.10E-01	4.51E-06	0.010
Cs-134	5.3E+00	1.9E+00	2.4E+00	2.4E-06	6.02E-02	1.44E-07	—
Cs-135	1.7E-02	6.1E-03	7.6E-03	7.6E-09	4.43E-03	3.37E-11	—
Cs-137	1.2E+04	4.2E+03	5.2E+03	5.2E-03	1.16E-01	6.03E-04	1.31
Eu-152	4.6E+02	1.7E+02	2.0E+02	2.0E-04	1.05E-01	2.10E-05	0.046
Eu-154	3.9E+02	1.4E+02	1.7E+02	1.7E-04	8.49E-02	1.44E-05	0.031
Eu-155	8.4E+01	3.0E+01	3.7E+01	3.7E-05	3.74E-03	1.38E-07	—
Fr-221	2.4E-08	8.7E-09	1.1E-08	1.1E-14	5.42E-08	5.96E-22	—
Gd-152	1.3E-14	4.6E-15	5.8E-15	5.8E-21	0.0E+00	0.0E+00	—
H-3	2.3E+01	8.5E+00	1.0E+01	1.0E+01 ^a	2.23E-05	2.23E-04	0.486
Hf-181	3.7E-37	1.3E-37	1.6E-37	1.6E-43	1.25E-03	1.27E-44	—
Ho-166m	1.3E-06	4.6E-07	5.7E-07	5.7E-13	4.46E-01	2.54E-13	—
I-129	6.1E-01	2.2E-01	2.7E-01	2.7E-01 ^a	1.64E-01	4.43E-02	96.6
In-115	2.7E-12	9.9E-13	1.2E-12	1.2E-18	5.29E-02	6.35E-20	—
K-40	9.1E-01	3.3E-01	4.1E-01	4.1E-07	8.67E-02	3.55E-08	—
Kr-85	5.5E+02	2.0E+02	2.5E+02	2.5E+02 ^a	4.91E-08	1.23E-05	0.027
Mn-54	9.1E-09	3.3E-09	4.1E-09	4.1E-15	7.00E-03	2.87E-17	—
Nb-93m	6.4E-03	2.3E-03	2.9E-03	2.9E-09	2.37E-03	6.87E-12	—
Nb-94	4.2E-06	1.5E-06	1.9E-06	1.9E-12	4.75E-01	9.03E-13	—
Nb-95	2.3E-33	8.2E-34	1.0E-33	1.0E-39	2.52E-03	2.52E-42	—
Np-237	3.0E-01	1.1E-01	1.4E-01	1.4E-07	8.39E+00	1.17E-06	0.0026
Np-238	1.0E-07	3.7E-08	4.6E-08	4.6E-14	5.28E-04	2.43E-17	—
Np-239	1.6E-04	5.7E-05	7.1E-05	7.1E-11	5.55E-05	3.94E-15	—
Np-240	1.3E-14	4.8E-15	5.9E-15	5.9E-21	4.95E-06	2.92E-26	—
Np-240m	1.2E-11	4.3E-12	5.4E-12	5.4E-18	2.01E-08	1.09E-25	—
Pa-233	2.1E-02	7.4E-03	9.2E-03	9.2E-09	5.67E-04	5.22E-12	—

Table 3. (continued).

Radioactive Source	Total Landfill Activity (Ci)	Maximum Yearly Input 36% (Ci)	Scaling Factor 1.24 (Ci)	1E-06 Resuspension Factor (Ci)	Unit Dose (mrem/Ci)	MEI Dose at Boundary (mrem)	Major Radionuclides Percent Contribution to Dose (% of mrem)
Pa-234	1.3E-06	4.7E-07	5.8E-07	5.8E-13	4.11E-05	2.38E-17	—
Pa-234m	8.1E-04	2.9E-04	3.6E-04	3.6E-10	9.63E-18	3.47E-27	—
Pd-107	2.9E-03	1.0E-03	1.3E-03	1.3E-09	2.78E-04	3.61E-13	—
Pm-147	1.8E+02	6.5E+01	8.1E+01	8.1E-05	8.15E-04	6.60E-08	—
Pr-144	8.4E-04	3.0E-04	3.7E-04	3.7E-10	9.61E-08	3.56E-17	—
Pu-236	2.6E-06	9.4E-07	1.2E-06	1.2E-12	1.46E+00	1.75E-12	—
Pu-238	1.1E+02	4.0E+01	4.9E+01	4.9E-05	5.54E+00	2.71E-04	0.591
Pu-239	3.2E+00	1.1E+00	1.4E+00	1.4E-06	5.98E+00	8.37E-06	0.018
Pu-240	7.1E-01	2.6E-01	3.2E-01	3.2E-07	5.97E+00	1.91E-06	0.004
Pu-241	3.0E+01	1.1E+01	1.4E+01	1.4E-05	9.39E-02	1.31E-06	0.003
Pu-242	1.1E-04	4.1E-05	5.1E-05	5.1E-11	5.68E+00	2.90E-10	—
Pu-244	1.2E-11	4.3E-12	5.4E-12	5.4E-18	5.64E+00	3.05E-17	—
Ra-223	9.6E-06	3.5E-06	4.3E-06	4.3E-12	1.55E-01	6.67E-13	—
Ra-225	2.4E-08	8.7E-09	1.1E-08	1.1E-14	9.28E-02	1.02E-15	—
Ra-226	2.2E-01	8.1E-02	1.0E-01	1.0E-07	3.38E-01	3.38E-08	—
Ra-228	7.2E-11	2.6E-11	3.2E-11	3.2E-17	1.40E-01	4.48E-18	—
Rb-87	5.3E-06	1.9E-06	2.4E-06	2.4E-12	8.53E-03	2.05E-14	—
Ru-103	9.5E-30	3.4E-30	4.2E-30	4.2E-36	9.17E-04	3.85E-39	—
Ru-106	5.8E-03	2.1E-03	2.6E-03	2.6E-09	1.35E-02	3.51E-11	—
Sb-125	4.4E+00	1.6E+00	2.0E+00	2.0E-06	1.28E-02	2.56E-08	—
Sb-126	9.8E-03	3.5E-03	4.4E-03	4.4E-09	1.46E-03	6.42E-12	—
Sb-126m	7.0E-02	2.5E-02	3.1E-02	3.1E-08	1.19E-06	3.69E-14	—
Se-79	7.9E-02	2.8E-02	3.5E-02	3.5E-08	0.0E+00	0.0E+00	—
Sm-147	1.9E-06	7.0E-07	8.7E-07	8.7E-13	1.22E+00	1.06E-12	—
Sm-151	1.6E+02	5.8E+01	7.1E+01	7.1E-05	5.58E-04	3.96E-08	—
Sn-126	7.0E-02	2.5E-02	3.1E-02	3.1E-08	4.07E-02	1.26E-09	—
Sr-90	1.1E+04	3.9E+03	4.8E+03	4.8E-03	7.57E-02	3.63E-04	0.791
Tc-99	2.7E+00	9.8E-01	1.2E+00	1.2E-06	1.56E-02	1.87E-08	—
Th-227	8.6E-06	3.1E-06	3.8E-06	3.8E-12	1.89E-01	7.18E-13	—
Th-228	1.6E-02	5.6E-03	7.0E-03	7.0E-09	4.05E+00	2.84E-08	—
Th-229	2.4E-08	8.7E-09	1.1E-08	1.1E-14	1.13E+01	1.24E-13	—
Th-230	8.2E-02	3.0E-02	3.7E-02	3.7E-08	4.05E+00	1.50E-07	—
Th-231	7.6E-02	2.7E-02	3.4E-02	3.4E-08	1.52E-05	5.17E-13	—

Table 3. (continued).

Radioactive Source	Total Landfill Activity (Ci)	Maximum Yearly Input 36% (Ci)	Scaling Factor 1.24 (Ci)	1E-06 Resuspension Factor (Ci)	Unit Dose (mrem/Ci)	MEI Dose at Boundary (mrem)	Major Radionuclides Percent Contribution to Dose (% of mrem)
Th-232	7.4E-02	2.7E-02	3.3E-02	3.3E-08	9.79E+00	3.23E-07	—
Th-234	8.1E-04	2.9E-04	3.6E-04	3.6E-10	1.46E-03	5.26E-13	—
U-232	2.5E-04	9.1E-05	1.1E-04	1.1E-10	8.03E+00	8.83E-10	—
U-233	1.2E-05	4.4E-06	5.4E-06	5.4E-12	2.30E+00	1.24E-11	—
U-234	2.9E+00	1.0E+00	1.3E+00	1.3E-06	2.25E+00	2.93E-06	0.006
U-235	5.2E-02	1.9E-02	2.3E-02	2.3E-08	2.14E+00	4.92E-08	—
U-236	9.6E-02	3.4E-02	4.3E-02	4.3E-08	2.13E+00	9.16E-08	—
U-238	9.2E-01	3.3E-01	4.1E-01	4.1E-07	2.00E+00	8.20E-07	0.002
U-240	1.2E-11	4.3E-12	5.4E-12	5.4E-18	3.57E-05	1.93E-22	—
Zn-65	1.3E-09	4.6E-10	5.7E-10	5.7E-16	2.14E-02	1.22E-17	—
Zr-93	4.1E-01	1.5E-01	1.8E-01	1.8E-07	9.78E-04	1.76E-10	—
Zr-95	1.4E-25	5.0E-26	6.2E-26	6.2E-32	1.91E-03	1.18E-34	—
Total	2.5E+04	8.8E+03	1.1E+04	2.6E+02	—	4.59E-02	100

a. 100% release was assumed for these radionuclides because they are in a gaseous form.

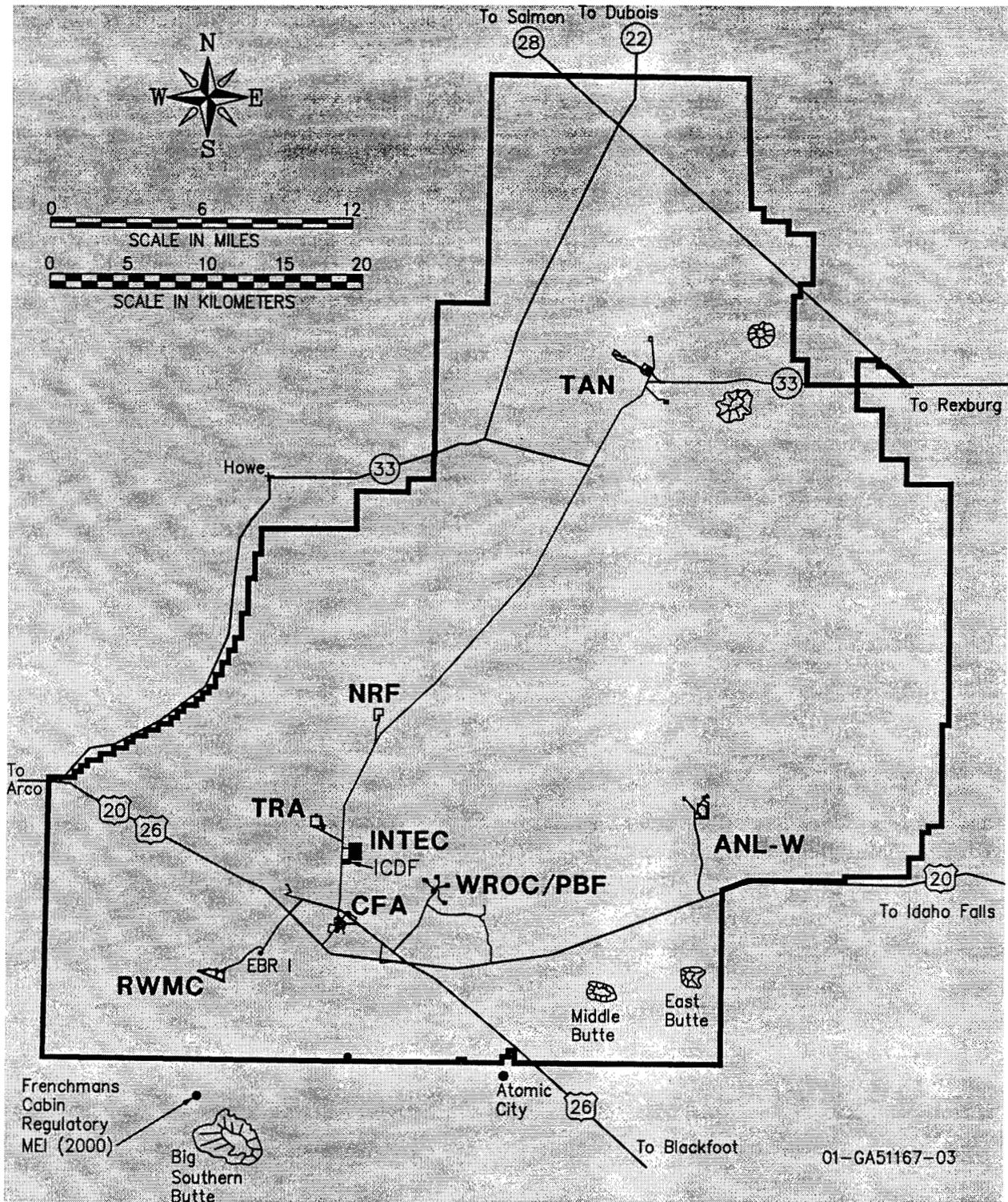


Figure 1. Location of 2000 MEI in relation to the INEEL and the ICDF Complex.

4. EVAPORATION POND ESTIMATED SOURCE TERM AND DOSE CALCULATIONS

The landfill is designed to collect any leachate and transfer it to the evaporation pond. As water moves down through the contaminated soil in the landfill, it will collect a certain amount of radioactive nuclides.

The concentration of radioactivity in the leachate will be estimated using partition coefficients. “The soil retention parameter in most assessment models is the soil/liquid partition coefficient, K_d . The K_d model assumes that the liquid and solid phases are at equilibrium and that there is a linear relationship between solute concentration in the solid (C_s) and liquid (C_L) phases....” (Sheppard and Thibault 1990).

The basic equation for the partition coefficient is

$$C_s = K_d C_L \quad (1)$$

where

C_s is the solute concentration in the solid, g/kg (i.e., activity in the soil)

C_L is the solute concentration in the liquid, g/L (i.e., activity in the liquid)

K_d is the partition coefficient, L/kg.

The partition coefficient equation may be rearranged to calculate the concentration of solute in water, C_L .

$$C_s = (K_d)(C_L)$$

$$C_L = \frac{C_s}{K_d} \quad (2)$$

The units for C_L are shown below.

$$C_L = \frac{C_s}{K_d} = \frac{\left(\frac{g}{kg}\right)}{\left(\frac{L}{kg}\right)} = \frac{g \times kg}{kg \times L} = \frac{g}{L}$$

The K_d values used for this analysis are those developed specifically for Idaho Nuclear Technology and Engineering Center (INTEC) waste material (Jenkins 2001) and are included in Appendix C.

4.1 Calculating Radioactivity in the Leachate

Data:

^{90}Sr total activity, 10,835 Ci

Landfill volume, 510,000 yd^3 .

Leachate volume, 857,224 gal/yr

K_d , 12 L/kg for ^{90}Sr in sand

Soil density, 95 lb/ft^3 ($1.16 \times 10^6 \text{ g}/\text{yd}^3$)

C_s , the concentration of ^{90}Sr in the soil is in Ci/kg

C_L , the concentration of ^{90}Sr in the liquid is in Ci/L.

The partition coefficient equation remains the same.

$$C_s = (K_d)(C_L) \quad (1)$$

The calculation for determining the concentration of ^{90}Sr in the liquid is

$$C_L = \frac{C_s}{K_d} \quad (2)$$

The units for C_L are Ci/L:
$$C_L = \frac{C_s}{K_d} = \frac{\left(\frac{\text{Ci}}{\text{kg}}\right)}{\left(\frac{\text{L}}{\text{kg}}\right)} = \frac{\text{Ci} \times \text{kg}}{\text{kg} \times \text{L}} = \frac{\text{Ci}}{\text{L}}$$

C_s and C_L are calculated below.

$$C_s = \left(\frac{\text{Ci } ^{90}\text{Sr}}{\text{landfill vol } \text{yd}^3} \right) \left(\frac{\text{yd}^3}{\text{soil density kg}} \right) = \frac{\text{Ci } ^{90}\text{Sr}}{\text{kg}} \quad (1)$$

Substitute values into the equation above determines C_s :

$$C_s = \frac{10,835 \text{ Ci } ^{90}\text{Sr}}{510,000 \text{ yd}^3} \left(\frac{\text{yd}^3}{1.16 \times 10^3 \text{ kg}} \right) = \frac{1.83 \times 10^{-5} \text{ Ci } ^{90}\text{Sr}}{\text{kg}} \quad (1)$$

C_L (Ci/L) is calculated using the following equation:

$$C_L = \frac{C_s}{K_d} \text{ where } C_s \text{ is } 1.83 \times 10^{-5} \text{ Ci } ^{90}\text{Sr} / \text{kg};$$

K_d is 12 L/kg.

Substituting values into the equation determines C_L :

$$C_L = \frac{C_s}{K_d} = \frac{\left(\frac{1.83 \times 10^{-5} \text{ Ci } ^{90}\text{Sr}}{\text{kg}} \right)}{\left(\frac{12 \text{ L}}{\text{kg}} \right)} = \frac{1.83 \times 10^{-5} \text{ Ci } ^{90}\text{Sr} \times \text{kg}}{\text{kg} \times 12 \text{ L}} = \frac{1.53 \times 10^{-6} \text{ Ci } ^{90}\text{Sr}}{\text{L}} \quad (2)$$

The total yearly activity in the leachate is calculated below:

$$\frac{1.53 \times 10^{-6} \text{ Ci } ^{90}\text{Sr}}{\text{L}} \left(\frac{3.7854 \text{ L}}{\text{gal}} \right) \left(\frac{857,224 \text{ gal}}{\text{yr}} \right) = \frac{4.95 \text{ Ci } ^{90}\text{Sr}}{\text{yr}}$$

4.2 Generalized Spreadsheet Calculations to Determine Radioactivity in Leachate

A spreadsheet was programmed to calculate the concentration of nuclides in the leachate (Ci/yr). The equations and documentation are shown below.

The following assumptions were used:

- Total landfill radioactivity, x Ci
- Total landfill volume, 510,000 yd³
- Soil density, $1.16 \times 10^6 \text{ kg/yd}^3$ (95 lb/ft³) (Perry 1995)
- For specific element, K_d (L/kg), $y = K_d$
- Leachate volume, 857,224 gal/yr.

$$C_s = C_L K_d \quad (1)$$

where

$$C_L = \text{Ci/L liquid}$$

$$K_d = \text{L/kg}$$

$$C_s = \text{Ci/kg solid.}$$

$$C_L = \frac{C_s}{K_d} = \frac{\left(\frac{Ci}{kg}\right)}{\left(\frac{L}{kg}\right)} = \frac{Ci \times kg}{kg \times L} = \frac{Ci}{L}$$

Substitute known values into the above equation

$$C_L = \frac{\left(\frac{x \text{ Ci}}{510,000 \text{ yd}^3}\right) \left(\frac{\text{yd}^3}{1.16 \times 10^3 \text{ kg}}\right)}{\left(\frac{y \text{ L}}{kg}\right) \left(\frac{\text{gal}}{3.7854 \text{ L}}\right) \left(\frac{\text{yr}}{857,224 \text{ gal}}\right)} \quad (2)$$

Rearrange the C_L equation and solve.

$$C_L = \left(\frac{x \text{ Ci}}{510,000 \text{ yd}^3}\right) \left(\frac{\text{yd}^3}{1.16 \times 10^3 \text{ kg}}\right) \left(\frac{kg}{y \text{ L}}\right) \left(\frac{3.7854 \text{ L}}{\text{gal}}\right) \left(\frac{857,224 \text{ gal}}{\text{yr}}\right)$$

$$C_L = \frac{x \text{ Ci} (5.49 \times 10^{-3})}{y}$$

The dose at the site boundary is estimated using unit curie data. This is the dose (mrem) that 1 curie would give to the maximally exposed individual located on the INEEL boundary.

$$\text{dose} = \frac{x \text{ Ci} (5.49 \times 10^{-3})}{y} \left(\frac{z \text{ mrem}}{\text{Ci}}\right)$$

Arrange the variables into a simpler format:

$$\text{mrem} = \frac{(x)(z)(5.49 \times 10^{-3})}{y}$$

where:

x is the activity of the radionuclide in curies

y is the K_d value in L/kg

z is the unit curie dose conversion in mrem/Ci.

Table 4 was utilized to check the spreadsheet results in calculating the dose from the landfill leachate.

Table 4. Verification for spreadsheet calculations determining leachate activity.

Source	Landfill Activity (Ci)	(x) Scaling Factor 1.24 (Ci)	(y) K_d Sand (L/kg)	(z) Unit Ci (mrem/Ci)	Conversion Factor	Dose ^a INEEL Boundary Using a 1/1,000 Resuspension Factor (mrem/yr)
⁶⁰ Co	9.2×10^1	1.1×10^2	10	0.111	5.49×10^{-3}	6.70×10^{-6}
⁹⁰ Sr	1.1×10^4	1.3×10^4	12	0.0764	5.49×10^{-3}	4.54×10^{-4}
¹³⁷ Cs	1.2×10^4	1.4×10^4	500	0.117	5.49×10^{-3}	1.80×10^{-5}
²³⁸ Pu	1.1×10^2	1.4×10^2	140	5.59	5.49×10^{-3}	3.07×10^{-5}
²³⁸ U	9.2×10^{-1}	1.1	6	2.02	5.49×10^{-3}	2.03×10^{-6}

a. The hand-calculated dose in this table varies slightly from those calculated in the spreadsheet. This is normal due to the extra significant figures used in the spreadsheet. It also used a 1/1,000 reduction factor.

The leachate is sent to the evaporation pond. The gaseous radionuclides have already been assumed to be released at the landfill. The remaining particulates are assumed to be released with a 1×10^{-3} release fraction. This is the same release fraction from liquid to air used in the 40 CFR 61, Appendix D, for determining “permit to construct” conditions.

Table 5 shows the dose from the leachate under the above assumptions. The landfill volume is assumed to be 510,000 yd³, with 857,224 gal/yr leachate. This makes the total radioactivity available for leaching with the exception of the gaseous radionuclides, which are accounted for at the landfill.

Table 6 shows the radioactivity estimated to go to the evaporation pond from the wells. Once in the pond, all of the tritium, krypton, and iodine are expected to be released, and, as with the leachate, 1×10^{-3} of the remaining particulate radionuclides are assumed to enter the air.

The total dose from the evaporation pond is shown in Table 7. This table assumes that all the water from the wells goes to the pond in 1 year and that all gaseous radionuclides are released. The dose from the landfill leachate assumes that the landfill is full and that all gaseous radionuclides have already been released when the soil was unloaded at the landfill.

Table 5. Full landfill, leachate radioactivity based on radioactive inventory and K_d values.

Source	Total Landfill Activity (Ci)	(x) Sealing Factor 1.24 (Ci)	Landfill Volume 510,000 yd ³ (Ci/yd ³)	Soil Density 1.16E+06 g/yd ³ (Ci/kg)	(y) K_d (L/Kg)	C_L (Ci/L)	Precipitation 857,234 gal/yr Leachate Curies (Ci)	10 ⁻³		
								Unit Ci Dose (mrem/Ci)	Resuspension Factor and Dose at INEEL Boundary (mrem)	Major Nuclides Percentage of Dose (% mrem)
Ac-225	2.4E-08	3.0E-08	5.9E-14	5.1E-17	450	1.1E-19	3.7E-13	1.01E-01	3.70E-17	—
Ac-227	9.7E-06	1.2E-05	2.4E-11	2.0E-14	450	4.5E-17	1.5E-10	1.08E+01	1.58E-12	—
Ac-228	7.2E-11	8.9E-11	1.8E-16	1.5E-19	450	3.4E-22	1.1E-15	2.02E-01	2.19E-19	—
Ag-109m	2.3E-12	2.9E-12	5.7E-18	4.9E-21	90	5.4E-23	1.8E-16	1.82E-25	3.22E-44	—
Ag-110	2.5E-11	3.0E-11	6.0E-17	5.1E-20	90	5.7E-22	1.9E-15	9.84E-35	1.80E-52	—
Ag-110m	2.6E-09	3.3E-09	6.4E-15	5.5E-18	90	6.1E-20	2.0E-13	2.26E-02	4.43E-18	—
Am-241	1.1E+01	1.4E+01	2.7E-05	2.4E-08	340	7.0E-11	2.3E-04	9.27E+00	2.10E-06	0.398
Am-242	2.1E-05	2.7E-05	5.2E-11	4.5E-14	340	1.3E-16	4.3E-10	8.76E-04	3.82E-16	—
Am-242m	2.1E-05	2.7E-05	5.2E-11	4.5E-14	340	1.3E-16	4.3E-10	8.93E+00	3.89E-12	—
Am-243	1.6E-04	2.0E-04	3.8E-10	3.3E-13	340	9.8E-16	3.2E-09	9.27E+00	2.99E-11	—
At-217	2.4E-08	3.0E-08	5.9E-14	5.1E-17	0	—	—	0.0E+00	—	—
Be-10	5.4E-07	6.7E-07	1.3E-12	1.1E-15	250	4.5E-18	1.5E-11	0.0E+00	0.0E+00	—
C-14	2.2E-05	2.7E-05	5.3E-11	4.6E-14	5	9.2E-15	3.0E-08	1.24E-03	3.68E-14	—
Cd-113m	7.7E-01	9.5E-01	1.9E-06	1.6E-09	6	2.7E-10	8.7E-04	0.0E+00	0.0E+00	—
Ce-144	8.6E-04	1.1E-03	2.1E-09	1.8E-12	500	3.6E-15	1.2E-08	8.98E-03	1.08E-13	—
Cm-243	1.7E-06	2.1E-06	4.1E-12	3.5E-15	4000	8.8E-19	2.9E-12	6.21E+00	1.79E-14	—
Cm-244	8.5E-04	1.1E-03	2.1E-09	1.8E-12	4000	4.5E-16	1.5E-09	4.89E+00	7.38E-12	—
Cm-245	3.8E-08	4.7E-08	9.2E-14	8.0E-17	4000	2.0E-20	6.5E-14	9.58E+00	6.18E-16	—
Cm-246	8.5E-10	1.1E-09	2.1E-15	1.8E-18	4000	4.4E-22	1.4E-15	9.47E+00	1.10E-17	—
Co-57	1.7E-03	2.2E-03	4.3E-09	3.7E-12	10	3.7E-13	1.2E-06	1.48E-03	1.79E-12	—

Table 5. (continued).

Source	Total Landfill Activity (Ci)	(x) Scaling Factor 1.24 (Ci)	Landfill Volume 510,000 yd ³ (Ci/yd ³)	Soil Density 1.16E+06 g/yc ³		(y) K _d (L/Kg)	Precipitation 857,234 gal/yr Leachate Curies (Ci)		Resuspension Factor and Dose at INEEL Boundary (mrem)		Major Nuclides Percentage of Dose (% mrem)
				C _s (Ci/kg)	C _L (Ci/L)		Unit Ci Dose (mrem/Ci)	Dose at INEEL Boundary (mrem)			
Co-58	2.8E-17	3.5E-17	6.8E-23	5.8E-26	10	1.9E-20	2.70E-03	5.19E-26	—	—	
Co-60	9.2E+01	1.1E+02	2.2E-04	1.9E-07	10	6.2E-02	1.11E-01	6.70E-06	1.27	1.27	
Cs-134	5.3E+00	6.6E+00	1.3E-05	1.1E-08	500	7.2E-05	6.08E-02	4.41E-09	—	—	
Cs-135	1.7E-02	2.1E-02	4.1E-08	3.6E-11	500	2.3E-07	4.47E-03	1.03E-12	—	—	
Cs-137	1.2E+04	1.4E+04	2.8E-02	2.4E-05	500	1.6E-01	1.17E-01	1.80E-05	3.41	3.41	
Eu-152	4.6E+02	5.7E+02	1.1E-03	9.6E-07	340	9.2E-03	1.06E-01	9.76E-07	0.185	0.185	
Eu-154	3.9E+02	4.8E+02	9.5E-04	8.2E-07	340	7.8E-03	8.57E-02	6.64E-07	0.126	0.126	
Eu-155	8.4E+01	1.0E+02	2.0E-04	1.8E-07	340	1.7E-03	3.77E-03	6.09E-09	0.001	0.001	
Fr-221	2.4E-08	3.0E-08	5.9E-14	5.1E-17	500	3.3E-13	5.68E-08	1.87E-23	—	—	
Gd-152	1.3E-14	1.6E-14	3.1E-20	2.7E-23	240	3.7E-19	0.0E+00	0.0E+00	—	—	
H-3	2.3E+01	2.9E+01	5.7E-05	4.9E-08	0	—	2.24E-05	a	—	—	
Hf-181	3.7E-37	4.6E-37	9.0E-43	7.7E-46	450	5.6E-42	1.26E-03	7.07E-48	—	—	
Ho-166m	1.3E-06	1.6E-06	3.1E-12	2.7E-15	250	3.5E-11	4.50E-01	1.58E-14	—	—	
I-129	6.1E-01	7.6E-01	1.5E-06	1.3E-09	0	—	1.66E-01	a	—	—	
In-115	2.7E-12	3.4E-12	6.7E-18	5.7E-21	390	4.8E-17	5.34E-02	2.56E-21	—	—	
K-40	9.1E-01	1.1E+00	2.2E-06	1.9E-09	15	4.1E-04	8.75E-02	3.52E-08	0.007	0.007	
Kr-85	5.5E+02	6.8E+02	1.3E-03	1.2E-06	0	—	4.95E-08	a	—	—	
Mn-54	9.1E-09	1.1E-08	2.2E-14	1.9E-17	50	1.2E-12	7.07E-03	8.54E-18	—	—	
Nb-93m	6.4E-03	7.9E-03	1.6E-08	1.3E-11	100	4.4E-07	2.39E-03	1.04E-12	—	—	
Nb-94	4.2E-06	5.2E-06	1.0E-11	8.8E-15	100	2.8E-10	4.79E-01	1.37E-13	—	—	
Nb-95	2.3E-33	2.8E-33	5.5E-39	4.8E-42	100	1.5E-37	2.55E-03	3.92E-43	—	—	
Np-237	3.0E-01	3.8E-01	7.4E-07	6.4E-10	8	2.6E-04	8.47E+00	2.21E-06	0.419	0.419	

Table 5. (continued).

Source	Total Landfill Activity (Ci)	(x) Sealing Factor 1.24 (Ci)	Landfill Volume 510,000 yd ³ (Ci/yd ³)	Soil Density 1.16E+06 g/yd ³		(y) K _d (L/Kg)	C _L (Ci/L)	Precipitation 857,234 gal/yr Leachate Curies (Ci)	(z) Unit Ci Dose (mrem/Ci)	Resuspension Factor and Dose at INEEL Boundary (mrem)		Major Nuclides Percentage of Dose (% mrem)
				C _s (Ci/kg)	(L/Kg)					10 ⁻³	10 ⁻³	
Np-238	1.0E-07	1.3E-07	2.5E-13	2.2E-16	8	2.7E-17	8.8E-11	5.33E-04	4.76E-17	—	—	
Np-239	1.6E-04	2.0E-04	3.8E-10	3.3E-13	8	4.1E-14	1.3E-07	5.61E-05	7.70E-15	—	—	
Np-240	1.3E-14	1.6E-14	3.2E-20	2.8E-23	8	3.5E-24	1.1E-17	5.03E-06	5.52E-26	—	—	
Np-240m	1.2E-11	1.5E-11	2.9E-17	2.5E-20	8	3.2E-21	1.0E-14	2.09E-08	2.15E-25	—	—	
Pa-233	2.1E-02	2.6E-02	5.0E-08	4.3E-11	550	7.9E-14	2.6E-07	5.72E-04	1.48E-13	—	—	
Pa-234	1.3E-06	1.6E-06	3.2E-12	2.7E-15	550	5.0E-18	1.6E-11	4.15E-05	6.63E-19	—	—	
Pa-234m	8.1E-04	1.0E-03	2.0E-09	1.7E-12	550	3.1E-15	1.0E-08	1.13E-17	1.13E-28	—	—	
Pd-107	2.9E-03	3.6E-03	7.0E-09	6.1E-12	55	1.1E-13	3.6E-07	2.81E-04	1.01E-13	—	—	
Pm-147	1.8E+02	2.2E+02	4.4E-04	3.8E-07	240	1.6E-09	5.1E-03	8.22E-04	4.14E-09	—	—	
Pr-144	8.4E-04	1.0E-03	2.0E-09	1.8E-12	240	7.3E-15	2.4E-08	9.83E-08	2.25E-18	—	—	
Pu-236	2.6E-06	3.2E-06	6.4E-12	5.5E-15	140	3.9E-17	1.3E-10	1.47E+00	1.84E-13	—	—	
Pu-238	1.1E+02	1.4E+02	2.7E-04	2.3E-07	140	1.7E-09	5.4E-03	5.59E+00	3.07E-05	5.8	—	
Pu-239	3.2E+00	3.9E+00	7.7E-06	6.6E-09	140	4.7E-11	1.5E-04	6.04E+00	9.24E-07	0.175	—	
Pu-240	7.1E-01	8.8E-01	1.7E-06	1.5E-09	140	1.1E-11	3.5E-05	6.03E+00	2.08E-07	0.039	—	
Pu-241	3.0E+01	3.8E+01	7.4E-05	6.3E-08	140	4.5E-10	1.5E-03	9.48E-02	1.41E-07	0.027	—	
Pu-242	1.1E-04	1.4E-04	2.8E-10	2.4E-13	140	1.7E-15	5.5E-09	5.74E+00	3.15E-11	—	—	
Pu-244	1.2E-11	1.5E-11	2.9E-17	2.5E-20	140	1.8E-22	5.9E-16	5.70E+00	3.35E-18	—	—	
Ra-223	9.6E-06	1.2E-05	2.3E-11	2.0E-14	100	2.0E-16	6.5E-10	1.56E-01	1.03E-13	—	—	
Ra-225	2.4E-08	3.0E-08	5.9E-14	5.1E-17	100	5.1E-19	1.7E-12	9.36E-02	1.54E-16	—	—	
Ra-226	2.2E-01	2.8E-01	5.5E-07	4.7E-10	100	4.7E-12	1.5E-05	3.41E-01	5.24E-09	—	—	
Ra-228	7.2E-11	8.9E-11	1.8E-16	1.5E-19	100	1.5E-21	4.9E-15	1.41E-01	6.89E-19	—	—	
Rb-87	5.3E-06	6.5E-06	1.3E-11	1.1E-14	55	2.0E-16	6.5E-10	8.61E-03	5.59E-15	—	—	

Table 5. (continued).

Source	Total Landfill Activity (Ci)	(x) Sealing Factor 1.24 (Ci)	Landfill Volume 510,000 yd ³ (Ci/yd ³)	Soil Density 1.16E+06 g/yd ³ C _s (Ci/kg)	(y) K _d (L/Kg)	C _L (Ci/L)	Precipitation 857,234 gal/yr Leachate Curies (Ci)	Unit Ci Dose (mrem/Ci)	10 ⁻³ Resuspension Factor and Dose at INEEL Boundary (mrem)		Major Nuclides Percentage of Dose (% mrem)
									9.5E-30	1.11E-39	
Ru-103	9.5E-30	1.2E-29	2.3E-35	2.0E-38	55	3.6E-40	1.2E-33	9.25E-04	1.11E-39	—	
Ru-106	5.8E-03	7.1E-03	1.4E-08	1.2E-11	55	2.2E-13	7.1E-07	1.36E-02	9.64E-12	—	
Sb-125	4.4E+00	5.4E+00	1.1E-05	9.2E-09	50	1.8E-10	6.0E-04	1.30E-02	7.71E-09	0.001	
Sb-126	9.8E-03	1.2E-02	2.4E-08	2.0E-11	50	4.1E-13	1.3E-06	1.47E-03	1.94E-12	—	
Sb-126m	7.0E-02	8.7E-02	1.7E-07	1.5E-10	50	2.9E-12	9.5E-06	1.22E-06	1.17E-14	—	
Se-79	7.9E-02	9.7E-02	1.9E-07	1.6E-10	4	4.1E-11	1.3E-04	0.0E+00	0.0E+00	—	
Sm-147	1.9E-06	2.4E-06	4.7E-12	4.1E-15	240	1.7E-17	5.5E-11	1.24E+00	6.81E-14	—	
Sm-151	1.6E+02	2.0E+02	3.9E-04	3.4E-07	240	1.4E-09	4.5E-03	5.63E-04	2.58E-09	—	
Sn-126	7.0E-02	8.7E-02	1.7E-07	1.5E-10	130	1.1E-12	3.7E-06	4.11E-02	1.51E-10	—	
Sr-90	1.1E+04	1.3E+04	2.6E-02	2.3E-05	12	1.9E-06	6.1E+00	7.64E-02	4.54E-04	86.0	
Tc-99	2.7E+00	3.4E+00	6.6E-06	5.7E-09	0.2	2.9E-08	9.3E-02	1.58E-02	1.47E-06	0.278	
Th-227	8.6E-06	1.1E-05	2.1E-11	1.8E-14	100	1.8E-16	5.9E-10	1.90E-01	1.15E-13	—	
Th-228	1.6E-02	1.9E-02	3.8E-08	3.3E-11	100	3.3E-13	1.1E-06	4.09E+00	4.27E-09	—	
Th-229	2.4E-08	3.0E-08	5.9E-14	5.1E-17	100	5.1E-19	1.7E-12	1.14E+01	1.88E-14	—	
Th-230	8.2E-02	1.0E-01	2.0E-07	1.7E-10	100	1.7E-12	5.6E-06	4.09E+00	2.25E-08	0.004	
Th-231	7.6E-02	9.5E-02	1.9E-07	1.6E-10	100	1.6E-12	5.2E-06	1.53E-05	7.98E-14	—	
Th-232	7.4E-02	9.2E-02	1.8E-07	1.5E-10	100	1.5E-12	5.0E-06	9.88E+00	4.99E-08	0.009	
Th-234	8.1E-04	1.0E-03	2.0E-09	1.7E-12	100	1.7E-14	5.5E-08	1.47E-03	8.07E-14	—	
U-232	2.5E-04	3.1E-04	6.2E-10	5.3E-13	6	8.9E-14	2.9E-07	8.10E+00	2.30E-09	—	
U-233	1.2E-05	1.5E-05	2.9E-11	2.5E-14	6	4.2E-15	1.4E-08	2.32E+00	3.18E-11	—	
U-234	2.9E+00	3.5E+00	6.9E-06	6.0E-09	6	1.0E-09	3.2E-03	2.27E+00	7.27E-06	1.38	
U-235	5.2E-02	6.5E-02	1.3E-07	1.1E-10	6	1.8E-11	5.9E-05	2.16E+00	1.28E-07	0.024	

Table 5. (continued).

Source	Total Landfill Activity (Ci)	(x) Scaling Factor 1.24 (Ci)	Landfill Volume 510,000 yd ³ (Ci/yd ³)	Soil		Precipitation 857,234 gal/yr Leachate Curies (Ci)	Resuspension Factor and Dose at INEEL Boundary (mrem)	Major Nuclides Percentage of Dose (% mrem)	
				Density 1.16E+06 g/yd ³ C _s (Ci/kg)	(y) K _d (L/Kg)				
U-236	9.6E-02	1.2E-01	2.3E-07	2.0E-10	6	1.1E-04	2.15E+00	2.36E-07	0.045
U-238	9.2E-01	1.1E+00	2.2E-06	1.9E-09	6	1.0E-03	2.02E+00	2.03E-06	0.384
U-240	1.2E-11	1.5E-11	2.9E-17	2.5E-20	6	1.4E-14	3.60E-05	4.94E-22	—
Zr-65	1.3E-09	1.6E-09	3.1E-15	2.7E-18	16	5.4E-13	2.16E-02	1.19E-17	—
Zr-93	4.1E-01	5.0E-01	9.9E-07	8.5E-10	600	4.6E-06	9.87E-04	4.52E-12	—
Zr-95	1.4E-25	1.7E-25	3.4E-31	2.9E-34	600	1.6E-30	1.92E-03	2.99E-36	—
Total	2.5E+04	3.0E+04	6.0E-02	5.1E-05	—	6.5	—	5.28E-04	100

a. Gaseous radionuclides are assumed to be released at the landfill, hence, there would not be any remaining in the leachate.

Table 6. Well water volumes, radioactive sources, and estimated doses at the INEEL boundary (DOE-ID 1997).

Source	Perched Water		SRPA / OU 3-14		Dose from all well water			Radionuclides Percentage of Dose at INEEL Boundary (% of mrem)
	Maximum (pCi/L)	30,000 Gallons Total (Ci)	Maximum (pCi/L)	300,000 Gallons Total (Ci)	Unit Ci Dose (mrem/Ci)	Unmitigated (Perch Ci + SRPA Ci)*Unit Dose (mrem)	Dose to Boundary 1/1,000 (mrem)	
Am-241	1.60E-01	1.82E-08	5.40E-01	6.13E-07	9.27E+00	5.85E-06	5.85E-09	0.11
H-3	7.30E+04	8.29E-03	3.10E+04	3.52E-02	2.24E-05	9.74E-07	9.74E-07	18.3
I-129	0.00E+00	0.00E+00	3.82E+00	4.34E-06	1.66E-01	7.20E-07	7.20E-07	13.5
Pu-238	1.70E-01	1.93E-08	0.00E+00	0.00E+00	5.59E+00	1.08E-07	1.08E-10	0.002
Pu-239	1.10E+03	1.25E-04	1.00E+01	1.14E-05	6.04E+00	8.24E-04	8.24E-07	15.5
Sr-90	3.20E+05	3.63E-02	8.40E+01	9.54E-05	7.64E-02	2.78E-03	2.78E-06	52.2
Tc-99	7.40E+02	8.40E-05	4.50E+02	5.11E-04	1.58E-02	9.40E-06	9.40E-09	0.18
U-234	1.10E+01	1.25E-06	2.60E+00	2.95E-06	2.27E+00	9.53E-06	9.53E-09	0.18
U-238	2.80E+00	3.18E-07	1.10E+00	1.25E-06	2.02E+00	3.17E-06	3.17E-09	0.06
Total		4.5E-02		3.6E-02		3.63E-03	5.33E-06	100

Notes:

Gross alpha in water samples was assumed to be Pu-239 for dose calculations.

Gross beta was not included because the major beta emitters were analyzed and included in dose calculations.

The maximum concentration of each radionuclide found in perched and SRPA water samples was used.

A reduction factor of 1,000 was used to estimate the amount entering the air.

All the H-3 and I-129 were assumed to be released.

The total dose assumes that all the well water goes to the evaporation pond in 1 year.

Table 7. Total dose from the evaporation pond (combined leachate and well water).

Source	Landfill Leachate (mrem)	Well Water (mrem)	Evaporation Pond Total Dose (mrem)	Major Radionuclide Dose Distribution (percentage)
Ac-225	3.70E-17	—	3.70E-17	—
Ac-227	1.58E-12	—	1.58E-12	—
Ac-228	2.19E-19	—	2.19E-19	—
Ag-109m	3.22E-44	—	3.22E-44	—
Ag-110	1.80E-52	—	1.80E-52	—
Ag-110m	4.43E-18	—	4.43E-18	—
Am-241	2.10E-06	5.85E-09	2.11E-06	0.396
Am-242	3.82E-16	—	3.82E-16	—
Am-242m	3.89E-12	—	3.89E-12	—
Am-243	2.99E-11	—	2.99E-11	—
At-217	—	—	0.00E+00	—
Be-10	0.00E+00	—	0.00E+00	—
C-14	3.68E-14	—	3.68E-14	—
Cd-113m	0.00E+00	—	0.00E+00	—

Table 7. (continued).

Source	Landfill Leachate (mrem)	Well Water (mrem)	Evaporation Pond Total Dose (mrem)	Major Radionuclide Dose Distribution (percentage)
Ce-144	1.08E-13	—	1.08E-13	—
Cm-243	1.79E-14	—	1.79E-14	—
Cm-244	7.38E-12	—	7.38E-12	—
Cm-245	6.18E-16	—	6.18E-16	—
Cm-246	1.10E-17	—	1.10E-17	—
Co-57	1.79E-12	—	1.79E-12	—
Co-58	5.19E-26	—	5.19E-26	—
Co-60	6.70E-06	—	6.70E-06	1.26
Cs-134	4.41E-09	—	4.41E-09	—
Cs-135	1.03E-12	—	1.03E-12	—
Cs-137	1.80E-05	—	1.80E-05	3.38
Eu-152	9.76E-07	—	9.76E-07	0.183
Eu-154	6.64E-07	—	6.64E-07	0.125
Eu-155	6.09E-09	—	6.09E-09	0.001
Fr-221	1.87E-23	—	1.87E-23	—
Gd-152	0.00E+00	—	0.00E+00	—
H-3	a	9.74E-07	9.74E-07	0.183
Hf-181	7.07E-48	—	7.07E-48	—
Ho-166m	1.58E-14	—	1.58E-14	—
I-129	a	7.20E-07	7.20E-07	0.135
In-115	2.56E-21	—	2.56E-21	—
K-40	3.52E-08	—	3.52E-08	0.007
Kr-85	a	—	0.00E+00	—
Mn-54	8.54E-18	—	8.54E-18	—
Nb-93m	1.04E-12	—	1.04E-12	—
Nb-94	1.37E-13	—	1.37E-13	—
Nb-95	3.92E-43	—	3.92E-43	—
Np-237	2.21E-06	—	2.21E-06	0.414
Np-238	4.76E-17	—	4.76E-17	—
Np-239	7.70E-15	—	7.70E-15	—
Np-240	5.52E-26	—	5.52E-26	—
Np-240m	2.15E-25	—	2.15E-25	—
Pa-233	1.48E-13	—	1.48E-13	—
Pa-234	6.63E-19	—	6.63E-19	—
Pa-234m	1.13E-28	—	1.13E-28	—

Table 7. (continued).

Source	Landfill Leachate (mrem)	Well Water (mrem)	Evaporation Pond Total Dose (mrem)	Major Radionuclide Dose Distribution (percentage)
Pd-107	1.01E-13	—	1.01E-13	—
Pm-147	4.14E-09	—	4.14E-09	—
Pr-144	2.25E-18	—	2.25E-18	—
Pu-236	1.84E-13	—	1.84E-13	—
Pu-238	3.07E-05	1.08E-10	3.07E-05	5.76
Pu-239	9.24E-07	8.24E-07	1.75E-06	0.328
Pu-240	2.08E-07	—	2.08E-07	0.039
Pu-241	1.41E-07	—	1.41E-07	0.026
Pu-242	3.15E-11	—	3.15E-11	—
Pu-244	3.35E-18	—	3.35E-18	—
Ra-223	1.03E-13	—	1.03E-13	—
Ra-225	1.54E-16	—	1.54E-16	—
Ra-226	5.24E-09	—	5.24E-09	—
Ra-228	6.89E-19	—	6.89E-19	—
Rb-87	5.59E-15	—	5.59E-15	—
Ru-103	1.11E-39	—	1.11E-39	—
Ru-106	9.64E-12	—	9.64E-12	—
Sb-125	7.71E-09	—	7.71E-09	0.001
Sb-126	1.94E-12	—	1.94E-12	—
Sb-126m	1.17E-14	—	1.17E-14	—
Se-79	0.00E+00	—	0.00E+00	—
Sm-147	6.81E-14	—	6.81E-14	—
Sm-151	2.58E-09	—	2.58E-09	—
Sn-126	1.51E-10	—	1.51E-10	—
Sr-90	4.54E-04	2.78E-06	4.57E-04	85.7
Tc-99	1.47E-06	9.40E-09	1.48E-06	0.278
Th-227	1.15E-13	—	1.15E-13	—
Th-228	4.27E-09	—	4.27E-09	—
Th-229	1.88E-14	—	1.88E-14	—
Th-230	2.25E-08	—	2.25E-08	0.004
Th-231	7.98E-14	—	7.98E-14	—
Th-232	4.99E-08	—	4.99E-08	0.009
Th-234	8.07E-14	—	8.07E-14	—
U-232	2.30E-09	—	2.30E-09	—
U-233	3.18E-11	—	3.18E-11	—

Table 7. (continued).

Source	Landfill Leachate (mrem)	Well Water (mrem)	Evaporation Pond Total Dose (mrem)	Major Radionuclide Dose Distribution (percentage)
U-234	7.27E-06	9.53E-09	7.28E-06	1.36
U-235	1.28E-07	—	1.28E-07	0.024
U-236	2.36E-07	—	2.36E-07	0.044
U-238	2.03E-06	3.17E-09	2.03E-06	0.381
U-240	4.94E-22	—	4.94E-22	—
Zn-65	1.19E-17	—	1.19E-17	—
Zr-93	4.52E-12	—	4.52E-12	—
Zr-95	2.99E-36	—	2.99E-36	—
Total	5.28E-04	5.33E-06	5.33E-04	100

a. These gaseous radionuclides are assumed to be completely released from the landfill as a gas.

5. CONCLUSION

This report estimates the radioactive dose to the MEI for the proposed operation of the ICDF landfill and the evaporation pond just south of INTEC.

Major assumptions used when estimating the radioactivity from the landfill and evaporation pond are the following:

1. Landfill activity released to air is based on
 - (a) Maximum yearly input of 36% of the total
 - (b) Activity multiplier (1.24) based on the additional volume required to completely fill the landfill.

The yearly air emissions will not be greater than the maximum activity handled or entering the landfill in any 1 year. Gaseous radionuclides are assumed to be released in the year they enter the landfill. An overall resuspension factor of 1×10^{-6} was applied to all the activity arriving in the landfill during this year.

2. Leachate is based on a full landfill and all the radioactivity it will contain.

The activity in the leachate will not be greater than the total activity in the landfill. The maximum yearly leachate activity would be when the landfill is completely full.

3. Purge water from all wells is assumed to go to the evaporation pond in 1 year.

The estimated volume of purge water through 2007 is about 330,000 gal. The radioactivity is based on using the maximum concentration for each radionuclide applied to the perched water and the maximum concentration found in the aquifer is applied to all the SRPA water and OU 3-14. This maximized the radioactivity in the water.

The above assumptions result in making the estimated dose an enveloping value. That is, it should encompass all activities at the landfill and evaporation pond during any given year. The dose is the best estimate of the maximum dose one would receive at the Site boundary in 1 year. During that year, 36% of the total radioactivity going to the landfill would be received. At the same time, the radioactivity available for leaching from the landfill is set at 100% of the total radioactive inventory that will be in the landfill. (In reality, these two conditions will not occur in the same year.)

Table 8 summarizes the estimated yearly dose to the Site boundary based on assumptions outlined in this report.

The conclusion from Table 8 is that the landfill is the major dose source with ^{129}I contributing almost all of that dose. The physical nature of ^{129}I will control the MEI dose. If ^{129}I is attached to a nonvolatile soil chemical, then the dose to the MEI will be significantly reduced. However, the dose will not be greater than that listed in Table 8 because of the conservative assumption that all ^{129}I is gaseous.

Therefore, emissions from neither the landfill nor the evaporation pond present any unacceptable risk to the MEI.

Table 8. Estimated dose at the INEEL boundary from the operation of the landfill and evaporation pond.

Facility	Landfill Resuspension Factor	Major Radionuclide Contributors to Dose
	1×10^{-6} (mrem/yr)	
Landfill operation	4.59×10^{-2}	^{129}I – 96.6%, ^{137}Cs – 1.3%
Evaporation pond (Total)	5.33×10^{-4}	^{90}Sr – 86.0%, ^{238}Pu – 5.8%
Well water	(5.33×10^{-6})	(^{90}Sr – 52.2%, ^3H – 18.3%, ^{239}Pu – 15.5%, ^{129}I – 13.5%)
Leachate	(5.28×10^{-4})	(^{90}Sr – 86.0%, ^{238}Pu – 5.8%, ^{137}Cs – 3.4%)
Total dose	4.64×10^{-2}	^{129}I – 95.5%, ^{137}Cs – 1.3%, ^{90}Sr – 1.8%

Note: The leachate and the well water doses have been listed separately and then combined to provide a total dose for the evaporation pond.

6. REFERENCES

- 40 CFR 61.96, 2001, "Applications to construct or modify," *Code of Federal Regulations*, Office of the Federal Register, July 1, 2001.
- 40 CFR 61, Appendix D, 2000, "Methods for Estimating Radionuclide Emissions," *Code of Federal Regulations*, Office of the Federal Register, July 1, 2000.
- Beres, D. A., 1990, "A Dose and Risk Assessment Methodology for Radionuclide Emissions to Air," *The Clean Air Assessment Package—1998 (CAP-88)*, Vol. 1.
- Brodsky, A., 1980, "Resuspension Factors and Probabilities Of Intake Of Materials in Process (Or "Is 10^{-6} a Magic Number in Health Physics?")," *Health Physics*, Volume 39, Number 6, p. 992.
- DOE-ID, 1997, *Comprehensive RI/FS for the Idaho Chemical Processing Plant OU 3-13 at the INEEL—Part A, RI/BRA Report (Final)*, DOE/ID-10534, Rev. 0, November 1997.
- DOE-ID, 1999, *Final Record of Decision, Idaho Nuclear Technology and Engineering Center, Operable Unit 3-13*, DOE/ID-10660, Rev. 0, October 1999.
- DOE-ID, 2000, *CERCLA Waste Inventory Database Report for the Operable Unit 3-13 Waste Disposal Complex*, DOE/ID-10803, Rev. 0, December 2000.
- EDF-ER-264, 2001, "INEEL CERCLA Disposal Facility Design Inventory," Rev. 0, Environmental Restoration Program, July 2001.
- EDF-ER-269, 2001, "Leachate Generation Study (Title I)," Rev. 0, Environmental Restoration Program, July 2001.
- EDF-1540, 2000, "Staging, Storage, Sizing, and Treatment Facility (SSSTF) Waste Inventory Design Basis," Rev. 0, Environmental Restoration Program, January 2000.
- EDF-1547, 2000, "Staging, Storage, Sizing, and Treatment Facility (SSSTF), SSSTF/ICDF Operational Scenario and Process Flow," Rev. 0, Environmental Restoration Program, January 2001.
- Healy, J. W., 1982, "Review of Resuspension Models," *Transuranic Elements in the Environment*, Technical Information Center, Volume 43, No. 2, pp. 269-272, August 1982.
- INEEL, 1998, *Air Modeling Protocol*, INEEL/INT-98-00236, July 1998.
- Jenkins, Talley, DOE-ID, to Martin Doornbos, BBWI, July 3, 2001, "Selection of K_d Values for INTEC Groundwater Modeling," EM-ER-01-115.
- McKenzie-Carter, M. D. Otis, M. E. Anderson, J. A. Roberts, R. L. Gotchy, R. A. Meck, March 1999, *Radiological Assessments for Clearance of Equipment and Materials From Nuclear Facilities*, NUREG-1640 Volume 1, Science Applications International Corporation, Prepared for Division of Regulatory Applications, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission.

Perry, John, 1995, *Perry's Chemical Engineers' Handbook, Approximate Specific Gravities and Densities of Miscellaneous Solids and Liquids*, New York, McGraw-Hill Book Company, Sixth Edition, page 3–95, Table 3–118, March 1995.

Sheppard, M. I., and D. H. Thibault, 1990, "Default Soil Solid/Liquid Partition Coefficients, K_{ds} , for Four Major Soil Types: A Compendium," *Health Physics*, Vol. 59, Number 4, pp 471–482.

Appendix A
SSSTF NESHAP Evaluation

Appendix A

SSSTF NESHAP Evaluation

Summary

The SSSTF was evaluated as part of the 30% design using 40 CFR 61.96 to determine if an application for approval to construct was required. The source term was derived using 40 CFR 61 Appendix D. The source term was modeled and the effective dose equivalent was determined to be 0.006 mrem/yr. This is less than the 0.1 mrem/yr limit below which no application is required.

Since the preparation of the 30% design, further assessment of the waste streams has eliminated the majority of the wastes originally calculated to be managed at the SSSTF. Elimination of waste streams (and volumes) originally in the 30% design calculations will reduce the radioactivity being released. A new analysis is not required because it has been shown that if all of the original waste identified in the 30% design could be processed without exceeding the 0.1 mrem/yr limit then processing less activity will reduce the original source term. Therefore, the emissions from the SSSTF are not a permitting or monitoring concern.

Discussion

SSSTF Airborne Radionuclide Source Term and Doses (30% Design Evaluation)

The following assumptions were made in developing the airborne radionuclide releases from the SSSTF:

- Only wastes undergoing stabilization in SSSTF have potential for radiological emissions; soils going to ICDF without treatment are not considered in SSSTF source term.
- Handling/stabilizing soil represents a worst case from an emissions standpoint; bounds other SSSTF releases.
- For each release site, maximum radionuclide concentrations measured in soil are assumed for all soil from that release site (maximums are from EDF-ER-264, "ICDF Design Summary."
- All waste being stabilized is treated as soil, i.e., total waste volume is assumed to be soil at maximum radionuclide concentrations.
- Release fraction of 1E-03 for particulate radionuclides assumed per 40 CFR 61, Appendix D (NESHAP Guidance).
- No cleanup of airborne releases from SSSTF is credited.
- Spreadsheet "Waste Schedule 9-27-00" used to allocate source terms by year (Table A-1).
- Source term calculation:
 - $$\text{Total Ci radionuclide } i \text{ in waste} = \text{Vol waste (yd}^3\text{)} \times 0.765 \text{ m}^3/\text{yd}^3 \times 1 \times 10^6 \text{ cc/m}^3 \times 1.5 \text{ g/cc (soil density)} \times \text{measured level of radionuclide } i \text{ (pCi/g)} \times 1 \text{ Ci}/1 \times 10^{12} \text{ pCi}$$

$$i \text{ Ci waste} = \left(\frac{i \text{ pCi}}{\text{g soil}} \right) \left(\frac{\text{yd}^3}{\text{yr}} \right) \left(\frac{0.765 \text{ m}^3}{\text{yd}^3} \right) \left(\frac{1 \times 10^6 \text{ cc}}{\text{m}^3} \right) \left(\frac{1.5 \text{ g soil}}{\text{cc}} \right) \left(\frac{\text{Ci}}{1 \times 10^{12} \text{ pCi}} \right)$$

- Release of radionuclide i (Ci) = Total Ci radionuclide i in waste $\times 1 \times 10^{-3}$

$$i \text{ Ci released} = \left(\frac{i \text{ Ci waste}}{1,000} \right)$$

- Doses modeled with CAP88 dispersion/dose code
 - Ground-level release
 - 10-year average meteorology from 10-m level of NOAA's Grid 3 tower
 - Dose to maximally exposed individual at INEEL boundary, 13900 m SSW.

To determine if a point source requires monitoring the potential to emit radioactivity is calculated. The potential to emit is based on the discharge of the effluent stream that would result if all pollution control equipment did not exist, but the facility's operations were otherwise normal.

For INEEL NESHAP permitting purposes it has been decided that the MEI receptor location will be on the INEEL boundary rather than at the location determined for the annual NESHAP report. This is because the actual MEI has the potential to be different from year to year. The worst-case MEI at the site boundary will bound any actual location.

The MEI location is determined by screening calculations using CAP88. Doses are calculated for INEEL boundary locations that are closest within each of the 16 compass direction sectors. For facilities on the south end of the INEEL, the MEI is within the south southwest sector. This is because the predominate nocturnal air movement is from the north northeast and the ICDF Complex is much closer to the southern INEEL boundary.

For purposes of NESHAP, multiple-year average meteorology is used. The latest long-term average wind files from National Oceanic and Atmospheric Administration are 10-year averages from 1987 through 1996. The NOAA-provided 10-year average annual rainfall is 20.8 cm and the temperature is 279 K (6°C).

Table A-1 shows that the maximum dose for any year from SSSTF using Appendix D would be 6.0×10^{-5} mrem/yr. This is less than the permit-to-construct limit of 0.1 mrem/yr; therefore, no approval to construct is required.

The potential to emit is also shown in Table A-1 to be 6.0×10^{-3} mrem, which is less than 0.1 mrem/yr. This means that the point source from SSSTF does not require continuous monitoring.

Table A-1. SSSTF waste stabilization worst-case doses to the MEI.

Year	Release Site	Volume (yd ³)	"Potential to emit" Dose without HEPAs (memrem/yr)	"Appendix D" Dose with HEPAs (mrem/yr)
2001	CFA-04*	800	1.1×10^{-4}	1.1×10^{-6}
2003	Borax-01	11,110	5.2×10^{-3}	5.2×10^{-5}
2004	ARA-12	1,000	6.0×10^{-3}	6.0×10^{-5}
	ARA-25	36		
	WRRTF-1	20,070		
	CPP-92*	1,370		
	CPP-98*	250		
	CPP-99*	126		
2005	ARA-12	1,000	7.1×10^{-5}	7.1×10^{-7}
	ARA-25	36		

* Note: The waste marked with an (*) will be treated in the SSSTF. The remaining waste streams will not go to the SSSTF for processing.

Conclusion

The SSSTF does not require an approval to construct per 40 CFR 61.96 nor does it need monitoring per 40 CFR 61.93 (b) (4).^a

This determination was initially made based on the SSSTF NESHAP evaluation during 30% design. Since that time, most of the waste streams have been removed from being processed in the SSSTF. This will reduce the radioactive emissions. Therefore, with less emissions the SSSTF will still not require an approval to construct or monitoring.

a. 40 CFR 61.93, 2001, "Emission Monitoring and Test Procedures," *Code of Federal Regulations*, Office of the Federal Register, July 1, 2001.

Appendix B
Unit Dose Calculations

Appendix B

Unit Dose Calculations

Table B-1. Unit dose calculations.

Radioactive Source	Landfill 13,160 m Unit Dose (mrem/Ci)	Pond 13,069 m Unit Dose (mrem/Ci)	Radioactive Source	Landfill 13,160 m Unit Dose (mrem/Ci)	Pond 13,069 m Unit Dose (mrem/Ci)
Ac-225	9.98E-02	1.01E-01	Pa-234m	9.63E-18	1.13E-17
Ac-227	1.07E+01	1.08E+01	Pd-107	2.78E-04	2.81E-04
Ac-228	2.00E-01	2.02E-01	Pm-147	8.15E-04	8.22E-04
Ag-109m	1.38E-25	1.82E-25	Pr-144	9.61E-08	9.83E-08
Ag-110	6.35E-35	9.84E-35	Pu-236	1.46E+00	1.47E+00
Ag-110m	2.24E-02	2.26E-02	Pu-238	5.54E+00	5.59E+00
Am-241	9.18E+00	9.27E+00	Pu-239	5.98E+00	6.04E+00
Am-242	8.67E-04	8.76E-04	Pu-240	5.97E+00	6.03E+00
Am-242M	8.85E+00	8.93E+00	Pu-241	9.39E-02	9.48E-02
Am-243	9.18E+00	9.27E+00	Pu-242	5.68E+00	5.74E+00
C-14	1.23E-03	1.24E-03	Pu-244	5.64E+00	5.70E+00
Ce-144	8.89E-03	8.98E-03	Ra-223	1.55E-01	1.56E-01
Cm-243	6.15E+00	6.21E+00	Ra-225	9.28E-02	9.36E-02
Cm-244	4.85E+00	4.89E+00	Ra-226	3.38E-01	3.41E-01
Cm-245	9.49E+00	9.58E+00	Ra-228	1.40E-01	1.41E-01
Cm-246	9.38E+00	9.47E+00	Rb-87	8.53E-03	8.61E-03
Co-57	1.46E-03	1.48E-03	Ru-103	9.17E-04	9.25E-04
Co-58	2.67E-03	2.70E-03	Ru-106	1.35E-02	1.36E-02
Co-60	1.10E-01	1.11E-01	Sb-125	1.28E-02	1.30E-02
Cs-134	6.02E-02	6.08E-02	Sb-126	1.46E-03	1.47E-03
Cs-135	4.43E-03	4.47E-03	Sb-126m	1.19E-06	1.22E-06
Cs-137	1.16E-01	1.17E-01	Sm-147	1.22E+00	1.24E+00
Eu-152	1.05E-01	1.06E-01	Sm-151	5.58E-04	5.63E-04
Eu-154	8.49E-02	8.57E-02	Sn-126	4.07E-02	4.11E-02
Eu-155	3.74E-03	3.77E-03	Sr-90	7.57E-02	7.64E-02
Fr-221	5.42E-08	5.68E-08	Tc-99	1.56E-02	1.58E-02
H-3	2.23E-05	2.24E-05	Th-227	1.89E-01	1.90E-01
Hf-181	1.25E-03	1.26E-03	Th-228	4.05E+00	4.09E+00
Ho-166m	4.46E-01	4.50E-01	Th-229	1.13E+01	1.14E+01
I-129	1.64E-01	1.66E-01	Th-230	4.05E+00	4.09E+00

Table B-1. (continued).

Radioactive Source	Landfill	Pond	Radioactive Source	Landfill	Pond
	13,160 m Unit Dose (mrem/Ci)	13,069 m Unit Dose (mrem/Ci)		13,160 m Unit Dose (mrem/Ci)	13,069 m Unit Dose (mrem/Ci)
In-115	5.29E-02	5.34E-02	Th-231	1.52E-05	1.53E-05
K-40	8.67E-02	8.75E-02	Th-232	9.79E+00	9.88E+00
Kr-85	4.91E-08	4.95E-08	Th-234	1.46E-03	1.47E-03
Mn-54	7.00E-03	7.07E-03	U-232	8.03E+00	8.10E+00
Nb-93m	2.37E-03	2.39E-03	U-233	2.30E+00	2.32E+00
Nb-94	4.75E-01	4.79E-01	U-234	2.25E+00	2.27E+00
Nb-95	2.52E-03	2.55E-03	U-235	2.14E+00	2.16E+00
Np-237	8.39E+00	8.47E+00	U-236	2.13E+00	2.15E+00
Np-238	5.28E-04	5.33E-04	U-238	2.00E+00	2.02E+00
Np-239	5.55E-05	5.61E-05	U-240	3.57E-05	3.60E-05
Np-240	4.95E-06	5.03E-06	Zn-65	2.14E-02	2.16E-02
Np-240m	2.01E-08	2.09E-08	Zr-93	9.78E-04	9.87E-04
Pa-233	5.67E-04	5.72E-04	Zr-95	1.91E-03	1.92E-03
Pa-234	4.11E-05	4.15E-05			

Appendix C

K_d Values

Appendix C

K_d Values

Table C-1. Partition coefficients, K_d values, for sand similar to ICDF.^a

Nuclide	Preference						Selected K _d Value for Leachate (INEEL)	Notes
	#1	#2	#3	#4	#5	#6		
	EDF-ER-170 ^b	OU 3-13 RI/BRA ^c	Track 1 ^d	Sheppard and Thibault ^e	NCRP 123 ^f	EPA 402-R-99-004A ^g		
Ac	—	—	—	450	420	—	450	
Ag	—	90	90	90	90	—	90	
Al	—	250	—	—	—	—	250	
Am	340	340	340	1900	1900	—	340	
Ar	—	—	—	—	—	—	0	Gaseous element.
As	3	3	3	—	110	—	3	
At	—	—	—	—	—	—	0	This is a halogen with similar properties to iodine. (CRC 61 st edition ^h)
Au	—	—	—	—	30	—	30	
B	—	—	—	—	—	—	5	Chemically similar to carbon. (CRC 61 st edition)
Ba	—	50	50	—	52	—	50	
Be	—	250	250	250	240	—	250	
Bi	—	—	100	100	120	—	100	
Bk	—	—	—	—	—	—	4000	Chemical similar to Cm based on valence states and actinide chemistry. (CRC 61 st edition)
Br	—	—	15	15	14	—	15	
C	—	—	0	5	6.7	—	5	Assumed to not be gaseous.
Ca	—	—	5	5	8.9	—	5	
Cd	—	6	6	80	40	8	6	
Ce	—	—	500	500	500	—	500	
Cf	—	—	—	—	510	—	510	
Cl	—	0	—	—	1.7	—	0	
Cm	—	—	—	4000	4000	—	4000	
CN-	—	—	0	—	—	—	0	
Co	—	10	10	60	60	—	10	
Cr	—	1.2	1.2	70	30	70	30	Assumed to not be Cr+6.
Cs	500	500	500	280	270	30	500	

Table C-1. (continued).

Nuclide	Preference						Selected K _d Value for Leachate (INEEL)	Notes
	#1	#2	#3	#4	#5	#6		
	EDF-ER- 170 ^b	OU 3-13 RI/BRA ^c	Track 1 ^d	Sheppard and Thibault ^e	NCRP 123 ^f	EPA 402- R-99- 004A ^g		
Cu	—	20	20	—	30	—	20	
Dy	—	—	—	—	—	—	240	Same as other rare earth elements.
Er	—	—	—	—	—	—	240	Chemistry similar to other rare earth elements.
Eu	—	340	—	—	240	—	340	
F	—	0	0	—	87	—	0	
Fe	—	—	220	220	160	—	220	
Fr	—	—	—	—	—	—	500	Chemical similar to cesium. (CRC 61 st edition)
Ga	—	—	—	—	—	—	250	Chemically similar to aluminum and indium in relation to periodic table.
Gd	—	—	—	—	240	—	240	
Ge	—	—	—	—	—	—	35	Chemically similar to silicon and tin in relation to periodic table.
H	—	0	0	—	0	—	0	
He	—	—	—	—	—	—	0	Gaseous element.
Hf	—	—	—	450	—	—	450	
Hg	100	100	100	—	19	—	100	
Ho	—	—	—	250	240	—	250	
I	0	0	0	1	1	—	—	
In	—	—	—	—	390	—	390	
Ir	—	—	—	—	91	—	91	
K	—	15	15	15	18	—	15	
Kr	—	—	—	—	0	—	0	
La	—	—	—	—	1200	—	1200	
Li	—	—	—	—	—	—	15	Alkali metal element similar to potassium. (CRC 61 st edition)
Lu	—	—	—	—	—	—	240	Chemistry similar to other rare earth elements.
Mg	—	—	—	—	—	—	5	Chemically similar to calcium.
Mn	—	50	50	50	50	—	50	
Mo	—	—	—	10	10	—	10	
N	—	0	—	—	—	—	0	Same movement as nitrate.
Na	—	—	—	—	76	—	76	
Nb	—	100	—	160	160	—	100	

Table C-1. (continued).

Nuclide	Preference						Selected K _d Value for Leachate (INEEL)	Notes
	#1	#2	#3	#4	#5	#6		
	EDF-ER- 170 ^b	OU 3-13 RI/BRA ^c	Track 1 ^d	Sheppard and Thibault ^e	NCRP 123 ^f	EPA 402- R-99- 004A ^g		
Nd	—	—	—	—	240	—	240	
Ne	—	—	—	—	—	—	0	Gaseous element.
Ni	—	100	100	400	400	—	100	
Np	8	8	—	5	5	—	8	
O	—	—	—	—	—	—	0	Gaseous element.
Os	—	—	—	—	190	—	190	
P	—	—	—	5	8.9	—	5	
Pa	—	—	—	550	510	—	550	
Pb	100	—	100	270	270	710	100	
Pd	—	—	—	55	52	—	55	
Pm	—	—	—	—	240	—	240	
Po	—	—	—	150	150	—	150	
Pr	—	—	—	—	240	—	240	
Pt	—	—	—	—	—	—	55	Chemically similar to palladium in relation to periodic table.
Pu	140	22	22	550	550	80	140	
Ra	—	—	100	500	500	—	100	
Rb	—	—	—	55	52	—	55	
Re	—	—	—	10	14	—	10	
Rh	—	—	—	—	52	—	52	
Rn	—	—	—	—	0	0	0	
Ru	—	0	—	55	55	—	55	
S	—	—	—	—	14	—	14	
Sb	—	50	50	45	45	—	50	
Sc	—	—	—	—	310	—	310	
Se	—	4	4	150	140	—	4	
Si	—	—	—	35	—	—	35	
Sm	—	—	—	245	240	—	240	Chose most conservative.
Sn	—	—	—	130	130	—	130	
Sr	12	12	24	15	15	15	12	
Ta	—	—	—	220	—	—	220	
Tb	—	—	—	—	240	—	240	

Table C-1. (continued).

Nuclide	Preference						Selected K _d Value for Leachate (INEEL)	Notes
	#1	#2	#3	#4	#5	#6		
Tc	EDF-ER-170 ^b 0.2	OU 3-13 RI/BRA ^c 0.2	Track 1 ^d —	Sheppard and Thibault ^e 0.1	NCRP 123 ^f 0.1	EPA 402- R-99- 004A ^g —	0.2	
Te	—	—	—	125	140	—	125	
Th	100	—	100	3200	3200	1700	100	
Ti	—	—	—	—	—	—	600	Chemically similar to zirconium in relation to periodic table.
Tl	—	100	—	—	390	—	100	
Tm	—	—	—	—	—	—	240	Chemistry similar to other rare earth elements.
U	6	6	6	35	15	63	6	
V	—	6	1000	—	—	—	6	
W	—	—	—	—	100	—	100	
Xe	—	—	—	—	0	—	0	
Y	—	—	—	170	190	—	170	
Yb	—	—	—	—	—	—	240	Chemistry similar to other rare earth elements.
Zn	—	—	16	200	200	—	16	
Zr	—	—	600	600	580	—	600	

Note: Dashes in the table indicate that no value is given in that document for the specific nuclide.

a. Doombos, M. H., BBWI, personal communication with attached spreadsheet to B.D Preussner, BBWI, subject: "K_d Table," Attachment: "Kd values for INTEC fate and transport," May 15, 2001.

b. EDF-ER-170, 2000, "Screening Model Results of a Mixed Low-Level Waste Disposal Facility Proposed for the Idaho National Engineering and Environmental Laboratory," Rev. 0, Environmental Restoration Program, November 2000.

c. DOE-ID, 1997, *Comprehensive RI/FS for the Idaho Chemical Processing Plant OU 3-13 at the INEEL - Part A, RI/BRA Report*, DOE/ID-10534, Rev. 0, November 1997.

d. DOE-ID, 1992, *Track 1 Sites: Guidance for Assessing Low Probability Hazard Sites at the INEL*, Appendix G, DOE/ID-10340(92), Rev. 1, July 1992.

e. Sheppard, M. I., and D. H. Thibault, 1990, "Default Soil Solid/Liquid Partition Coefficients, K_ds, for Four Major Soil Types: A Compendium," *Health Physics*, Vol. 59, Number 4, pp 471-482.

f. NCRP, 1996, "Screening Models for Release of Radionuclides to Atmosphere, Surface Water, and Ground," NCRP Report No. 123 I, Table 4.1, National Council on Radiation Protection and Measurements, January 1996.

g. EPA, 1999, "Understanding Variation in Partition Coefficient K_d Values," EPA 402-R-99-004A, U.S. Environmental Protection Agency, August 1999.

h. Weast, R. C. et al., eds., 1980, *Handbook of Chemistry and Physics*, 61st edition, Boca Raton, Florida: CRC Press.