MASTER

ENVIRONMENTAL EFFECTS FROM DISPOSAL OF DEFENSE HIGH-LEVEL RADIOACTIVE WASTES IN A GENERIC GEOLOGIC REPOSITORY

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INTRODUCTION

High-level radioactive wastes generated during the reprocessing of defense-related nuclear fuels are presently stored as calcined solids at the Idaho Chemical Processing Plant (ICPP). This method of handling nuclear waste has proved to be both safe and cost effective. However, for permanent disposal, the waste form and/or disposal location may need to be altered.

Many plans for nuclear waste management can be advanced; however, the preferred alternatives for the ICPP waste are in these general categories:

- (1) Continue current operations
- (2) Modify the waste form and dispose at the Idaho National Engineering Laboratory (INEL)
- (3) Modify the waste form and dispose at an off-site geologic repository
- (4) Remove actinides from the waste, dispose of the actinide-depleted waste at the INEL, and dispose of the actinide waste at an off-site geologic repository.

The environmental impacts of disposing of the waste at the INEL and transporting it to an off-site repository have been previously reported.¹ The radiological consequences of disposing of the wastes in a generic geologic repository are reported here. The calculations are based on the scenarios used in the preparation of the Draft Environmental Impact Statement;

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Management of Commercially Generated Radioactive Waste.² Calculations were completed for both the calcine and glass waste forms. Calcine will be "stabilized" by a heating process to remove residual nitrates and/or water; all other properties remain the same. The glass waste form has two sub-options, the actinide fraction of the waste made into a glass, and the calcine made into a glass.

METHODOLOGY

The scenarios considered for release from the repository which might result in exposure pathways to man and their estimated probabilities are:

- (1) Canister drop down the repository shaft (7×10^{-7} events/yr)
- (2) Meteorite impact (2×10^{-13} events/yr)
- (3) Fault fracture and flooding (2×10^{-13} events/yr)
- (4) Drilling into the repository (5×10^{-7} events/yr)
- (5) Solution mining in a salt formation (1×10^{-6} events/yr)

Possible maximum individual doses and population doses were calculated for each waste form and for incremental time periods extending to 100 million years after processing. Most scenarios could result in small doses to an assumed two million people living within 80 km (50 miles) of the repository. The drilling scenario would result in exposures to a limited number of people (25 was assumed). Forty million people could be exposed by eating contaminated salt from a solution-mining operation. Details of the assumptions and calculations can be found in Reference 3.

SOURCE TERMS

Worst-case source terms for the calculations were determined by considering the inventories of all consequential isotopes in the waste and allowing decay and in-growth of daughter products. These include all wastes projected to be calcined through the year 2020. At the base year of 2020 the total quantity of waste is 2×10^7 kg (4×10^7 lb) calcine (or equivalent if in another waste form). The concentrations of radionuclides used in all calculations are shown in Table 1.

RESULTS

Possible environmental impacts from disposal of ICPP wastes in a geologic repository are evaluated and compared for actinide glass, stabilized calcine, and glass waste forms. Calculated doses are reported as maximum event consequences, the maximum individual dose if an event actually occurs, and population doses, which take the population, time span, and probability of occurrence into account.

For disposing the actinide fraction of the waste as a glass, the highest maximum event consequence is 10,000 mrem as a result of intrusion into the waste by drilling. The probability of occurrence of this event is very low. An extremely unlikely meteorite impact on the repository would result in a 2000 mrem exposure. The other scenarios would result in insignificant maximum event consequences as shown in Table 2. The largest population dose comes from the solution mining scenario over long time periods (1 million years). The 69,000 man-rem dose is due mainly to the large number of people exposed (40 million) and the long time span. No individual would receive a dose higher than three mrem. The other scenarios would not cause any significant population doses over any time period as shown in Table 2. At no time does the population dose approach the dose from natural background radiation. Over any time period the largest total dose is only 0.000027 percent of the total dose to the same population due to background radiation.

For disposing the entire waste inventory as a calcine, the highest maximum consequence is 5600 mrem as a result of an extremely unlikely meteorite impact. The drilling and fault-flooding scenarios, which are also unlikely events, would result in individual doses of 640 and 160 mrem respectively. The solution mining and canister drop scenarios would cause much lower event consequences as shown in Table 2. The largest population dose (69,000 man-rem) comes from the solution mining scenario. The dose is the same as with actinide glass, because all the waste is released in this scenario. As with actinide glass, this dose is the result of the large population and long time span involved, not any significant individual doses. As shown in Table 2, no other significant population doses would occur. At no time does the population dose approach the dose from natural background radiation. The largest total dose over any time period is only 0.000027 percent of the total dose to the same population due to background radiation.

For disposing the entire ICPP waste inventory as a glass, the highest maximum event consequence is 5600 mrem as a result of an extremely unlikely meteorite impact. The drilling scenario, which is also unlikely, would result in a 430 mrem

Table 1. Initial Radionuclide Concentrations of Input Solid Wastes,⁴ All Options

Nuclide	Activity (Ci/kg)	Nuclide	Activity (Ci/kg)	Nuclide	Activity (Ci/kg)
⁷⁹ Se	6.4E05*	⁸⁷ Rb	3.6E-09	⁹⁰ Sr	1.3E+01
⁹⁰ Y	1.3E+01	⁹³ Zr	3.1E-04	⁹³ MnNb	7.5E-05
⁹⁹ Tc	2.1E-03	¹⁰⁶ Ru	9.7E-01	¹⁰⁶ Rh	9.7E-01
¹⁰⁷ Pd	2.0E-05	¹²⁶ Sn	3.2E-05	¹²⁶ MSb	3.2E-05
¹²⁶ Sb	3.2E-05	¹³⁴ Cs	3.3	¹³⁵ Cs	7.5E-05
¹³⁷ Cs	1.3E+01	¹³⁷ mBa	1.2E+01	¹⁴⁴ Ce	8.2
¹⁴⁴ Pr	8.2	¹⁴⁴ Nd	0.0**	¹⁴⁷ Pm	1.2E+01
¹⁴⁷ Sm	0.0**	¹⁵¹ Sm	1.7E-01	¹⁵⁴ Eu	1.8E-01
²²⁶ Ra	0.0**	²³⁰ Th	0.0**	²³³ Pa	0.0**
²³³ U	1.2E-12	²³⁴ U	4.3E-10	²³⁵ U	1.8E-09
²³⁶ U	1.0E-08	²³⁷ U	4.8E-12	²³⁸ U	1.0E-14
²³⁷ Np	4.8E-08	²³⁹ Np	0.0**	²³⁸ Pu	7.0E-02
²³⁹ Pu	7.0E-04	²⁴⁰ Pu	6.5E-04	²⁴¹ Pu	1.6E-01
²⁴² Pu	1.8E-06	²⁴¹ Am	9.8E-04	²⁴³ Am	8.3E-06
²⁴² Cm	6.5E-04	²⁴⁴ Cm	5.2E-04		
Total	8.5E+01				

* 6.4E-05 = 6.4×10^{-5} = 0.000064

** Initial input is 0.0 but they appear later as daughter products

Table 2 Radiological Consequences of Repository Disposal

Release Scenario	Maximum Event Consequence (mrem/event)	Population Dose (man-rem)		
		1,000 yr.	10,000 yr.	1 million yr.
<u>Actinide Glass</u>				
Canister Drop	0.003	1.6x10 ⁻⁶	1.6x10 ⁻⁶	1.6x10 ⁻⁶
Meteorite Impact	2,000	1.6x10 ⁻⁶	2.7x10 ⁻⁶	7.5x10 ⁻⁶
Fault & Flooding	11	0	1.3x10 ⁻¹²	2.2x10 ⁻⁶
Drilling	10,000	0	0.21	74
Solution Mining	3.0	0	72	69,000
TOTAL		3.2x10 ⁻⁶	72	69,000
<u>Stabilized Calcine</u>				
Canister Drop	0.002	1.0x10 ⁻⁶	1.0x10 ⁻⁶	1.0x10 ⁻⁶
Meteorite Impact	5,600	2.6x10 ⁻⁶	3.8x10 ⁻⁶	8.5x10 ⁻⁶
Fault & Flooding	160	0	150x10 ⁻⁹	32x10 ⁻⁶
Drilling	640	0	0.06	2.0
Solution Mining	3.0	0	72	69,000
TOTAL		3.6x10 ⁻⁶	72	69,000
<u>Glass</u>				
Canister Drop	0.00007	34x10 ⁻⁹	34x10 ⁻⁹	34x10 ⁻⁹
Meteorite Impact	5,600	2.6x10 ⁻⁶	3.8x10 ⁻⁶	8.5x10 ⁻⁶
Fault & Flooding	11	0	1.3x10 ⁻¹²	2.2x10 ⁻⁶
Drilling	430	0	0.04	1.3
Solution Mining	3.0	0	72	69,000
TOTAL		2.6x10 ⁻⁶	72	69,000

exposure. No other significant event consequences would occur from the other scenarios as shown in Table 2. The largest population dose (69,000 man-rem) comes from the solution mining scenario. The dose is again mainly due to the large population and long time span involved. No individual would receive a significant dose. All other population doses would be extremely low as shown in Table 2. The largest total dose over any time period is only 0.000027 percent of the total dose to the same population due to natural background radiation.

SUMMARY AND CONCLUSIONS

The highest maximum event consequence for any scenario and waste form is 10,000 mrem for the drilling scenario with actinide glass, which occurs 200,000 years after disposal. This dose is lower by factors of 16 and 23 for stabilized calcine and glass respectively. The second highest event consequence is 5600 mrem for stabilized calcine and glass and 2000 mrem for actinide glass from a meteorite impact. Both events have very low probabilities of occurrence, and the resulting doses would cause very few, if any, health effects. The only significant population dose is 69,000 man-rem from the solution mining scenario for all three waste forms over one million years. The dose, however, is due to the large exposed population; no one individual would receive more than three mrem. The solution mining scenario would not exist at all if the repository were in any geologic formation other than salt.

Doses to individuals and to the population for each waste form and time period can be compared to the impacts of leaving the waste at the ICPP. The impacts of leaving the waste at the ICPP are detailed in references 1, 2, 3, and 4. The two largest maximum event consequences for leaving the waste at the ICPP are 490,000 mrem resulting from a meteorite impact scenario and 100,000 mrem resulting from an airplane striking the facility (1×10^{-8} events/yr). A maximum event consequence of 180,000 mrem results from an accident scenario while transporting the waste to a geologic repository. The maximum event consequence once the waste is disposed in a geologic repository is 10,000 mrem resulting from a drilling scenario. The total population dose for all activities including operational and occupational exposures, transportation exposures, and exposures from intrusion and migration are shown as a ratio to the population dose from leaving the waste at the ICPP in Figure 1. Because of the projected exposures required to further treat the waste and transport it to a geologic repository, thousands of years are necessary for the population dose from the geologic repository disposal alternative to equal or be less than the population dose from leaving the waste at the ICPP.

Figure 1. Comparison of Population Dose Risks from Alternatives.

Once ICPP wastes are disposed in a geologic repository, no catastrophic or even dangerous doses could be received from any credible exposure scenario. No clear choice between alternative waste forms, based on potential radiation exposure after geologic disposal can be made from this analysis. Disposal in a geologic repository such as the generic one described here appears to be a safe method for management of ICPP high-level wastes.

REFERENCES

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