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RISK EVALUATIONS OF TRANSURANIC WASTE AT THE IDAHO NATIONAL ENGINEERING LABORATORY

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INTRODUCTION AND SUMMARY

Approximately 75% of the defense low-level transuranic (TRU) waste stored in the United States and 25% of the buried TRU waste is located at the Idaho National Engineering Laboratory (INEL). Studies have been performed to identify and evaluate technical alternatives for the long-term management of this waste. (The alternatives range from leaving the waste in place as is to reviewing, processing, and shipping it to an offsite geologic repository.) Among the evaluations that have been performed were preliminary risk evaluations.

The dose commitment and risk of hypothetical, near-term, accidental or uncontrolled releases of radionuclides have been evaluated for each alternative. "Near term" is defined as the time period up to 100 years following implementation of an alternative. "Risk" is defined, for a given release scenario, as the product of the release frequency (generally similar in value to the probability) and the dose commitment. For hypothetical, long-term release scenarios, occurring 100 years or more after implementation, only dose commitments were evaluated. Estimates of long-term probabilites were considered to be unreliable.

The following potential causes of radionuclide release have been studied: process and handling accidents, shipping accidents, natural events (e.g., earthquakes), man-caused events (e.g., airplane crashes), and future intrusion by individuals or small populations after loss of societal control over the waste. The hypothetical releases have been evaluated, in terms of dose commitment and (if pertinent) probability and risk, for all operational steps making up each concept.

The dominant scenarios in terms of near-term risk are (1) lava flow up through or over the waste, leading to airbone releases (the waste is located at the edge of a volcanic rift zone); (2) an explosion or a criticality accident in the waste-processing facility; and (3) a tornado strike or a fire during waste retrieval. The dominant long-term releases are (1) volcanic action; and (2) intrusion of people on the waste site.

Although substantial dose commitments to individual members of the public were calculated for the lava flow and intrusion scenarios, no prompt health effects would be expected from the exposures. The effects would be in the form of a slightly increased likelihood of latent cancer induction.

The results of these preliminary risk evaluations are being used to guide more detailed evaluations and design safety studies.

PAST AND CURRENT WASTE-MANAGEMENT PRACTICES AT THE INEL

Since 1954, low-level defense TRU waste has been received at the INEL Radioactive Waste Management Complex (RWMC). Through 1970, about 2.2 million ft^3 of such waste was buried in pits and trenches. About 0.5 million ft^3 of beta/gamma-emitting non-TRU waste was intermixed with the buried TRU waste, as was a considerable quantity of uranium-238. The volume of buried TRU waste has been reduced to about 2 million ft^3 by experimental retrieval campaigns.

The waste pits and trenches are typically 15 ft deep. There is generally a minimum of 2 ft of soil between the waste and the basalt below. The waste is covered with 3 ft of soil and 2 ft of compacted clay.

The TRU waste received since 1970 (about 1.2 million ft^3 through 1977 and 1.4 million ft^3 through 1979) has been placed into 20-yr retrievable storage above ground on asphalt pads. The waste is contained in fiberglass-covered wooden boxes, steel drums with polyethylene liners, or steel bins. The containers are stacked in layers. When a stack is about 16 ft high, it is covered with plywood, reinforced polyvinyl sheeting, and 3 ft of soil.

The containers for the stored waste are in good condition. However, the containers for the buried waste have deteriorated badly. Steel drums have corroded through; wood and cardboard containers have rotted. As a result of container deterioration, some of the soil immediately adjacent to the waste has become contaminated. (If the buried waste were retrieved, an estimated 3.75 million ft^3 of contaminated soil would also have to be retrieved.) Radionuclides have migrated as much as about 5 ft below the waste. However, because of the adsorptive properties of the sediments and basalts underlying the RWMC, these is almost no danger of radionuclides migrating downward to the Snake River Plain Aquifer (580 ft below) in significant concentrations.

More detailed discussions of past and current management practices and their effects on the environment can be found in Reference 1.

WASTE DESCRIPTION

The TRU waste is solid material contaminated with transuranics. The categories of waste suggest its physical characteristics: laboratory equipment (fume loads, glassware, etc.); process equipment (tanks, pumps, etc.); protective clothing; maintenance tools; evaporator sludge; filter sludge; and decontamination and decommissioning materials (lumber, concrete, etc.). Only about 20% of the waste, by volume, is combustible.

The waste may be hazardous chemically as well as radiologically. The buried waste, in particular, is believed to contain toxic chemicals and pyrophoric materials. The plutonium in the waste is principally in the oxide and nitrate forms.

Table I lists the principal radionuclides in the buried and stored TRU waste (References 1 and 2). For the buried waste, the data are listed at the time of emplacement and as decayed to 1985, the estimated year in which a long-term waste-management alternative (see a following section) would be implemented. For the stored waste, values are given for waste received through 1977, based on activity at the time of receipt, and for the total inventory projected to 1985. Table II gives the estimated inventories of radionuclides in the beta-gamma waste intermixed with the buried TRU waste (References 1 and 2).

Some of the radionuclides in the waste are long-lived. Hazard index calculations (References 1 and 2) show that the relative hazard (in air) of the stored waste is reduced by only a factor of 3 after 1000 years. and a factor of 400 after 1,000,000 years. For the buried waste, the factors of reduction are 1.5 and 45, respectively.

ALTERNATIVES FOR LONG-TERM MANAGEMENT

Environmental monitoring over the last several years (e.g., Reference 3) has not identified any near-term hazards to the public or the environment from the TRU waste at the RWMC. However, studies have been performed (References 1, 2, and 4) to identify and evaluate technical alternatives for the long-term management of the buried and stored TRU waste.

A large number of long-term management alternatives and subalternatives have been identified. Four conceptual alternatives for the stored waste have been evaluated (Reference 1): (1) leave the waste as is; (2) improve in-place continement (three subalternatives were examined); (3) retrieve and process the waste, then ship it to an offsite geologic repository; (4) retrieve and process the waste, then dispose of it at the INEL, though not necessarily at the RWMC. Various waste-processing methods have been evaluated, ranging from overpacking to incineration by slagging pyrolysis, the resulting waste form being a basalt-like casting of low leachability. Several methods for onsite disposal have been studied.

For the buried waste, closely corresponding alternatives have been evaluated (Reference 2). Four subalternatives, rather than three have been evaluated for in-place confinement. Two retrieval methods, involving remote-control and direct-control of the retrieval equipment, have been studied. Simple overpacking of the buried waste is not feasible because some of the waste is essentially uncontained in the soil. However, repackaging the unprocessed waste in new containers was evaluated.

The evaluations of the alternatives have principally addressed those aspects most amenable to quantitative analysis: budgetary costs; projected environmental effects, both radiological and nonradiological; radiological and nonradiological hazards to waste-management workers; and the radiological risk from accidental or uncontrolled releases of radionuclides.

Several public documents, presenting comparative evaluations of the long-term management alternatives, have been or are being prepared in connection with the National Environmental Policy Act (NEPA). First was the technical alternatives document (Reference 4). Next were the quantitative evaluations related to stored waste (Reference 1) and buried waste (Reference 2), both in support of environmental impact statements in preparation.

The proposed waste-management criteria of the U. S. Environmental Protection Agency (Reference 5) require risk evaluations in connection with waste-management decisions. Because of this potential requirement and the usefulness of risk evaluations, to the public and to governmental agencies, such evaluations are included in all the aforementioned public documents.

The risk evaluations are preliminary and scoping in nature, involving a total of only about four man-years of effort. Detailed design information is not available for the alternatives. Also, more than 60 alternatives and subalternatives required evaluation, each consisting of several waste-management operations. Nevertheless, even these preliminary risk evaluations have provided valuable, early insights into (1) which waste-management operations and which scenarios of radionuclide release are dominant; (2) which results are most uncertain; and (3) which scenarios need to be studied further.

RISK EVALUATION METHODS

The quantities calculated in the risk analysis (dose commitment, probability, and risk) and the time-period terminology used (near-term, long-term) have been discussed; so has the general approach. This section discusses in more detail the assumptions, pathways, methods, and scenarios related to the risk evaluations (References 1, 2, and 4).

Use of several general guidelines and simplifying assumptions was necessary to perform the evaluations. Normal operational releases and waste disposal at an offsite repository were evaluated elsewhere (References 1 and 2 and Reference 6, respectively). Sabotage was excluded.

For each alternative, implementation was assumed to begin in 1985. The campaign for retrieval and processing was assumed to last ten years for buried waste and ten years for stored waste. Near-term releases were assumed to occur in 1985; long-term releases, in 2085. These are the respective years of maximum waste inventory for the short-term and long-term periods. Demographic projections were based on 1% (geometric) increase per year in current populations until the year 2085. Constant population was assumed thereafter. Societal control of the waste was assumed to continue for 100 years after implementation of any alternative (Reference 5).

Probabilities and radionuclide release fractions under accident conditions were based, where possible, on data from RWMC operations or from other sources. In many cases, these quantities could be estimated only by use of engineering judgment or comparison with the quantities for similar scenarios.

Average compositions of the waste (Tables I and II) were used. For alternatives involving waste retrieval and processing, waste generated during the campaign (including decontamination and decommissioning waste) was added to the waste inventory. Contaminated soil was assumed to be treated in the same manner as TRU waste. Sorting of soil, based on contamination level, is believed infeasible. For shipment evaluations, the offsite repository was assumed to be located near Carlsbad, New Mexico.

Several types of release, each with several potential pathways to man, were evaluated. The most common type was an airborne "puff" (instantaneous) release, involving an assumed fraction of the radionuclide inventory. If appropriate, credit was taken for the decontamination factor attributed to facility-ventilation and process-offgas systems. Continuous airborne releases involving wind pickup, as from erosion - exposed waste over many years, were evaluated. Statistical average meteorological conditions at the INEL were assumed for both types of airborne releases. Deposition and resuspension of radionuclides were included. Uptake through the food chain was also evaluated.

No surface water exists at the INEL, so surface-water pathways were not studied.

Releases via groundwater were evaluated by conservatively assuming radionuclide transport through basalt and sediments to the Snake River Plain aquifer, 580 feet below the surface of the RWMC. Saturated-zone transport through the aquifer to wells, three miles distant (for maximum individual dose) and 80 miles distant (for population dose) was modeled analytically (References 1 and 2). This model has been found to agree with two other saturated-zone models, one analytical (Reference 4) and one finite element (Reference 7). Preliminary modeling of the unsaturated zone (Reference 7) indicates that the radionuclides would not be expected to migrate down to the aquifer.

The instrusion scenario involved a different type of release. After societal control over the waste had ended, an individual was assumed to dig into the waste, generating and inhaling a contaminated dust cloud. A small group of individuals was assumed to operate a homestead-type farm directly above the waste. The people would obtain their entire food supply from this farm and would breathe slightly contaminated air containing dust from above the waste.

Following are some of the analytical models used for the dose calculations. Complete references for these and the other models used are given in Appendix E of References 1 and 2. Atmospheric transport was analyzed using the MESODIF computer code. The deposition model of Pelletier and Voilleque was used, as was the resuspension approach of Healy. The saltation approach of Bagnold was used for wind pickup. Inhalation exposure calculations were made using the DACRIN code. The INREM code was used for evaluating ingestion pathways; EXREM III was used for external dose calculations. The groundwater transport model of Codell and Shreiber was used. All doses from accidental or uncontrolled releases were calculated for a 50-year dose commitment.

The types of hypothetical release scenarios have already been stated. Among the natural events studied were tornadoes and earthquakes. Long-term natural releases also included groundwater variation, glaciation, climate change, and a change in the channel of the Big Lost River, 2 miles from the RWMC. Two natural events are of particular interest. One is the failure of the Mackay Dam (e.g., by seismic forces), about 42 miles upstream from the RWMC on the Big Lost River. The resulting flood could conceivably cause radionuclides to migrate downward toward the Snake River Plain aquifer. (However, as discussed earlier, such downward migration might not occur in reality). The flood could also spread radionuclides over the nearby land area, to become available later for lofting and airborne transport. The second natural event is an explosive volcanic eruption up through the waste or a lava flow over the waste. The RWMC is located at the edge of a volcanic rift zone. Either scenario could result in release of a si able fraction of the radionuclides; however, lava flow might simply entomb the waste, with no resulting release.

Release scenarios studied for waste retrieval and processing included dropped containers, fires, aircraft impacts, tornadoes, and earthquakes. For processing, accidents such as explosions, criticality accidents, and rupture of the slagging pyrolysis gasifier or the waste heat boiler were also studied. Shipping accidents, occurring enroute to the Federal Repository, were evaluated. Because of the scoping nature of these studies, no logic models, such as event trees or fault trees, were used to identify and evaluate release scenarios. Similarly, no sophisticated mathematical treatment of probabilities was attempted because of the large uncertainties in the data.

RESULTS

Complete results of the studies are given in References 1 and 2. Table III briefly summarizes the results of the risk-dominant operations-related events for the buried TRU waste. The results for stored waste are generally similar. Events which could occur and produce the same result, even if the waste were left in place (e.g., lava flow), are excluded. For brevity, only results based on dose commitments to the lung are presented here. The term, "inventory release fraction," refers to the fraction of the total radionuclide inventory (not the fraction of radionuclides in the affected containers) assumed to be released to the environment.

Table IV briefly summarizes the results of the dominant scenarios for the leave-as-is alternative for buried waste. The results for stored waste are of a similar magnitude. Except for intrusion (a long-term scenario assumed to occur in 2085), the scenarios listed in the table are assumed to occur in 1985.

Longer-term results have also been calculated. Figure 1 shows the population dose to the lung for the dominant scenario (volcanic action) for the leave-as-is buried-waste alternative, as a function of time of release for the first 25,000 years. The maximum population dose commitment (to the lung) was calculated to be 1×10^5 man-rem. Modeling of the assumed subsurface migration of radionuclides after hypothetical flooding in 2085 has indicated that the maximum population dose commitment (to the bone) would occur 600,000 to 1,200,000 years into the future and would be only 1×10^{-3} man-rem.

CONCLUSIONS

The risk-analysis results indicate that the risks to the public from accidental releases during retrieval, processing, and shipping operations are extremely small. If the waste were left as is, the effects of uncontrolled releases on the public could be substantial, though not disastrous. There are two dominant scenarios. The first is volcanic action, a class of events of very low probability, but with a potentially large population dose commitment. The second is future intrusion on the waste site by individuals and small populations, after lapse of societal control. Large individual dose commitments could result, but no prompt severe health effects would be expected. The projected number of waste-induced cancer cases in the surrounding population would be negligible compared with the normal incidence.

It is interesting that the two release scenarios often cited as serious hazards in public comments on the buried TRU waste - earthquakes and radionuclide migration to the aquifer - were found to be of relatively small importance in terms of the various dose and risk measures used in these studies.

ACKNOWLEDGEMENT

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REFERENCES

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TABLE I

RADIONUCLIDE CONTENT OF BURIED AND STORED TRU WASTE

Uranium and Transuranic Radionuclides	Half-Life (Years)	Buried Waste, Curies		Stored Waste, Curies	
		Emplaced	As of January 1, 1985	Emplaced (through Dec. 31, 1977)	As of January 1, 1985
Pu-238	86.4	571.4	462	16,120	44,223
Pu-239	24,390	21,043	19,789	11,720	34,230
Pu-240	6,580	4,860	4,564	2,856	8,071
Pu-241	13.2	178,425	54,324	91,940	194,092
Pu-242	379,000	0.2	0.2	0.2	0.2
Am-241	458	48,007	46,548	45,740	133,284
Cm-244	17.6	0	0	1,113	2,343
U-233	162,000	0.5	0.5	527	1,486
U-235	710,000,000	0.3	0.3	0.001	0.002
U-238	4,510,000,000	68	68	0.002	0.003
Total Radioactivity		252,975	125,660	170,016	417,729

TABLE II

ESTIMATED ACTIVITY IN BETA-GAMMA WASTE MIXED WITH BURIED TRU WASTE

Beta-gamma Radionuclide	Half-life (years)	Curies Emplaced	Curies as of January 1, 1985
Co-60	5.27	99,000	4214.3
Ni-59	80,000	1,500	1500.0
Sr-90	29.0	1,000	563.5
Cs-137	30.17	1,000	576.2
Mixed activation products (Co-60)	5.27	6,000	255.4
Mixed fission products (Cs-137)	30.17	500	288.1
Unidentified beta-gamma	3.0	5,500	21.5
Short-lived beta-gamma	1.0	468,500	negligible
TOTALS		583,000	7419.0

TABLE III

RESULTS SUMMARY: DOMINANT OPERATIONS-RELATED EVENTS FOR BURIED TRANSURANIC WASTE [a,b]

Event	Inventory Release Fraction	Event Frequency, $year^{-1}$	Maximum Individual: Dose Commitment, rem	Maximum Individual: Risk, rem/year	Population: Dos Commitment, man-rem	Population: Risk, man-rem/year
Retrieval						
Tornado	6×10^{-7}	5×10^{-7}	2×10^{-3}	1×10^{-9}	3×10^{0}	2×10^{-6}
Transfer Accident (with Fire)	1×10^{-7}	2×10^{-6}	3×10^{-4}	6×10^{-10}	5×10^{-1}	1×10^{-6}
Processing by Slagging Byrolysis						
Criticality	NA[c]	5×10^{-6}	2×10^{-4}	1×10^{-9}	1×10^{-1}	5×10^{-7}
Tornado	3×10^{-9}	5×10^{-7}	9×10^{-6}	5×10^{-12}	2×10^{-2}	1×10^{-8}
Processing by Packaging Only						
Severe Earthquake	4×10^{-8}	4×10^{-8}	1×10^{-4}	4×10^{-12}	2×10^{-1}	8×10^{-9}
Fire	3×10^{-14}	1×10^{-2}	9×10^{-11}	9×10^{-13}	2×10^{-7}	2×10^{-9}
Shipment to Repository						
Shipping Accident	9×10^{-12}	9×10^{-7}	3×10^{-8}	3×10^{-14}	5×10^{-5}	5×10^{-11}

a Results are given for lung dose only.

b Includes risk-dominant scenarios related to retrieving, processing, and shipping the waste. Excludes scenarios which could occur even if the waste were left in place. All scenarios are assumed to occur in 1985.

c NA = Not applicable.

TABLE IV

RESULTS SUMMARY: DOMINANT SCENARIOS FOR LEAVE-AS-IS ALTERNATIVE FOR BURIED TRANSURANIC WASTE[a]

Event	Inventory Release Fraction	Event Frequency, $year^{-1}$	Maximum Individual		Population	
			Dose Commitment, rem	Risk rem/year	Dose, man-rem	Risk man-rem/year
Explosive Volcano	2×10^{-4}	3×10^{-8}	6×10^{-1}	2×10^{-8}	1×10^{3}	3×10^{-5}
Lava Flow[b]	1×10^{-2}	6×10^{-5}	3×10^{1}	2×10^{-3}	5×10^{4}	3×10^{0}
Mackay Dam[c]	1×10^{-4}	2×10^{-3}	9×10^{-5}	2×10^{-7}	1×10^{-3}	2×10^{-6}
Intrusion[d]						
Excavation	NA[e]	NC[f]	1×10^{-2}	NC	1×10^{1}[g]	NC
Farming (inhalation)	NA	NC	2×10^{1}	NC	2×10^{2}[h]	NC
Farming[i] (ingestion)	NA	NC	5×10^{0}	NC	5×10^{1}[h]	NC

[a]Results are only for lung dose from inhalation of radionuclides, unless otherwise specified. All scenarios are assumed to occur in 1985, unless otherwise specified.
[b] Based on worst-case assumptions.
[c]Waterborne pathway to man. Results are for bone dose only.
[d]Assumed to occur in 2085. Hazard index of waste will have decreased by only 5% from its value in 1985.
[e]NA = Not applicable.
[f]NC = Not calculated.
[g]Dose to offsite population. Does not include dose to intruders.
[h]Dose to intruder population, assumed to be ten people.
[i]Results are for bone dose only.