PERFORMANCE ASSESSMENT FOR DISPOSAL OF RADIOACTIVE WASTE AT CLIVE, UTAH

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ABSTRACT

A radiological performance assessment has been conducted for a low-level radioactive waste disposal site at Clive, Utah. The PATHRAE computer code was used to evaluate doses through a variety of environmental pathways, including external gamma exposure, radioactive dust inhalation, groundwater transport to a well, and offsite atmospheric transport. Five exposure scenarios were evaluated: an onsite worker, an offsite resident at the facility boundary, a post-closure intruder explorer, a post-closure intruder constructor, and a post-closure intruder resident. The projected doses for each scenario were then compared to the appropriate regulatory limits. The maximum concentration which would exceed no dose criterion was established, all pathways and exposure scenarios considered.

INTRODUCTION

The Utah Department of Health, Bureau of Radiation Control (UDH/BRC) regulates a radioactive waste disposal facility near Clive, Utah that is currently licensed to receive and dispose of naturally occurring radioactive material (NORM) wastes. UDH/BRC has received an application to allow the disposal of other large volume wastes (e.g., contaminated soil and contaminated structural materials) with low concentrations of other than NORM radioactive constituents.

The potential public health impacts associated with radioactive waste disposal at the Clive facility were assessed to identify limits on radionuclide concentrations in the wastes proposed for disposal to ensure that radiological doses to persons who might be exposed do not exceed prescribed regulatory limits (1).

METHODOLOGY

The PATHRAE computer model was used to estimate potential radiological doses (effective whole-body dose equivalent) to workers and the general public from radioactive waste disposal at the Clive facility. The off-site pathways include groundwater transport to a river or a well, surface (wind or water) erosion, facility overflow, and atmospheric transport. The on-site pathways include direct gamma exposure, dust inhalation, food grown on the waste site, biointrusion, and inhalation of radioactive gas.

For this assessment of the radiological risks from waste disposal at the Clive facility, potential exposures to on-site workers, off-site members of the general public, and post-closure site reclaimers were evaluated. Three reclaimer scenarios (intruder explorer, intruder-construction, and intruder-agriculture) were also modeled.

Exposures to individuals were calculated based on unit concentrations (1 pCi/g) of each radionuclide postulated to be present in waste disposed at the Clive facility. The radionuclides considered are listed in Table I. The projected dose based on the assumed unit concentration were then combined with applicable dose criteria to infer concentration limits for the safe disposal of waste at the Clive facility. The quotient of the applicable dose criteria and the projected dose rate provided scaling factors by which the unit concentrations were multiplied to determine the maximum permissible concentrations of each radionuclide in the waste.

REGULATORY ASSESSMENT

State and federal regulations were reviewed to identify requirements that may be applicable to waste disposal at the Clive facility and to identify dose criteria to be used in this risk assessment. The results of this review are summarized in Table II. State of Utah regulations for the land disposal of radioactive waste, which are modeled after and closely parallel the NRC's licensing requirements in 10 CFR 61 (2), were found to be generally applicable to the regulation of the Clive disposal facility as shown in Table III. Dose criteria (in terms of effective whole-body dose equivalent) adopted for this analysis include:

- 25 mrem/yr to any maximally exposed off-site individual and to the intruder-explorer.
- 100 mrem/yr for chronic exposure to a reclaimer after site closure (the intruder-agriculture scenario).
- 500 mrem for acute exposure to a reclaimer after site closure (the intruder-construction scenario).
- 1,250 mrem/quarter to an on-site worker during disposal operations.

DISPOSAL SYSTEM CHARACTERISTICS

The Clive disposal site is located in Tooele County approximately 140 km (85 road miles) west of Salt Lake City along Interstate 80. The facility is directly south of and adjacent to the cell used for the disposal of mill tailings that were removed from the former Vitro Chemical Company site in South Salt Lake City between 1984 and 1988.

The climate at the Clive site is arid desert with an average annual rainfall of about 13 cm (5 in) per year. The water in the groundwater system beneath the site is briny and contains high total dissolved solids and certain

TABLE I

Radionuclides Considered

Nuclide	Nuclide	Nuclide	Nuclide
Am-241	Ca-134	Pu-238	Sr-90
Am-243	Ca-137	Pu-239	Tc-99
C-14	Fe-55	Pu-240	Th-230
Cd-109	H-3	Pu-241	Th-232
Cm-242	I-129	Pu-241	Th-232
Cm-242	Mn-54	Pu-242	U-234
Cm-243	Na-22	Ra-226	U-235
Cm-243	Nb-94	Ra-226	U-236
Cm-244	Ni-59	Ru-106	U-238
Cm-244	Ni-63	Ru-106	U-Nat.
Co-57	Np-237	Sn-113	Zn-65
Co-60	Pu-238	Sr-90	

naturally-occurring radionuclides that make it unfit for human consumption. There are no perennial surface water bodies within 3.2 km (2 mi) of the site, nor even gullies that would indicate intermittent channelized flow. Several key site parameters are summarized in Table IV.

Most of the land within a 16 km (10 mi) radius of the site is public land administered by the Bureau of Land Management. There are no industrial, commercial, or residential activities within at least 10 miles of the site, and the lack of potable water makes the surrounding area an improbable location for any future developments, although the Clive area has recently been zoned for hazardous waste disposal by Tooele County.

The material proposed for disposal at the Clive facility will be placed into a disposal cell constructed partly above grade and partly below grade as shown in Fig. 1. The bottom of the cell consists of a scarified and re-compacted clay liner to retard seepage from the cell into undisturbed soil. The cell cover consists of a 2.30 m (7.5 ft) thick compacted clay liner which serves as a radon barrier, a 0.15 m (0.5 ft) thick layer of sand, and a 0.45 m (1.5 ft) thick layer of rip-rap. The top of the cell is sloped to facilitate rainwater runoff.

Wastes being considered for disposal include contaminated soil and structural debris with very low concentrations of radionuclides. Radionuclides assumed to be present include nuclides commonly encountered in radioactive materials and transuranics. For this analysis the radionuclides are considered to be dispersed uniformly throughout the waste.

RISK ASSESSMENT

The exposure scenarios evaluated for this risk assessment and the exposure pathways included in the characterization of exposure scenarios are summarized in Table V.

Exposure pathways evaluated for on-site workers included dust inhalation and direct gamma exposure. These same exposure pathways were evaluated for an off-site individual during facility operations. For an off-site individual after site closure, the potential exposure pathways include groundwater, surface-water, and surface erosion pathways.

Since the intruder-explorer does not disturb the disposed waste, the only exposure pathway evaluated for this reclaimer was direct gamma exposure. Pathways evaluated for the construction intruder were direct gamma exposure and dust inhalation. Exposure pathways evaluated for the agricultural intruder included direct gamma exposure, dust inhalation, food consumption, and groundwater to a well. For the intruder-construction and intruder-agriculture scenarios, dose assessments were made at the end of the

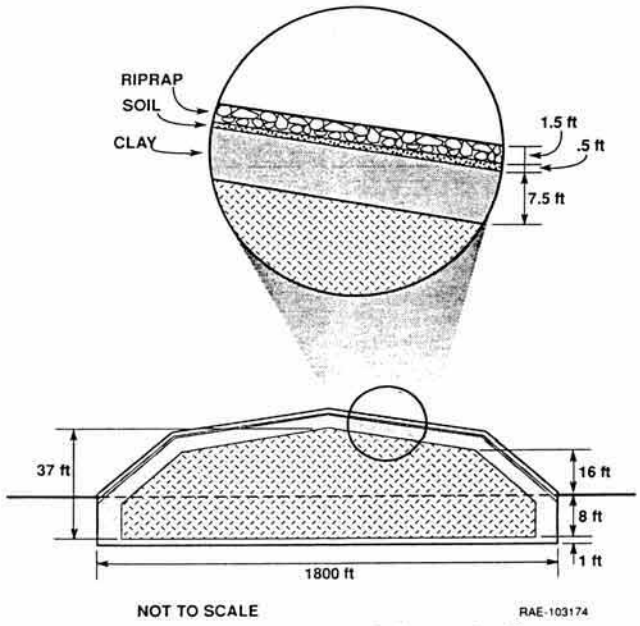

Fig. 1. Cross section of disposal cell.

TABLE II

Comparison of Waste Disposal Requirements and Risks.

Parameter	NRC-Licensed Commercial LLW Facility[a]			Mill Tailings	BRC Waste	Recommended for Clive Disposal Facility				
	General Public	Intruder	On-Site Worker			General Public	Intruder-Explorer	Intruder-Agriculture	Intruder-Construction	On-Site Worker
Dose Criterion	25 mrem/yr	500 mrem	5,000 mrem/yr	Radon Flux Limit[b]	1 to 10 mrem/yr	25 mrem/yr	25 mrem/yr	100 mrem/yr	500 mrem	1,250 mrem/qtr
Risk (HE/yr)[c]	7.0×10^{-6}	1.4×10^{-4}	1.4×10^{-3}	4.6×10^{-5}[d]	2.8×10^{-7} to 2.8×10^{-6}	7.0×10^{-6}	7.0×10^{-6}	2.8×10^{-5}	1.4×10^{-4}	1.4×10^{-3}
Generator Requirements	Regulated			Regulated	Regulated[e]	May or May Not be Regulated				
Disposal Facility Requirements	Regulated			Regulated	Not Regulated	Regulated				

a) Doses limited by 10 CFR 20 and 10 CFR 61
b) The radon flux limit is 20 pCi/m^2-sec which is assumed to provide the same health protection as an air concentration standard of 0.5 pCi/l at the edge of the tailings pile.
c) Conversion from dose to risk is based on a risk conversion factor of 2.8×10^{-7} health effects (fatal cancers) per millirem of effective dose equivalent (Reference 19).
d) Based on a radon concentration level of 0.5 pCi/l at the site boundary and a risk conversion factor of 360 fatal lung cancers per 10^6 WLM (Reference 20).
e) The waste generator is required to implement compliance procedures and maintain auditable records demonstrating that the waste meets prescribed radionuclide concentration and total curie limits.

TABLE III

Classification Summary for Waste Disposal Regulations

Requirement	Applicability	Rationale
State of Utah Requirements for LLW Disposal		
Performance Objectives	Applicable	Provide standards for the safety of the public and the environment.
Site Suitability Requirements	Applicable	Clive site's natural features appear to meet the prescribed site suitability requirements.
Facility Design Requirements	Applicable	Design must provide for isolation of the waste from man and his environment. Clive site's natural features facilitate isolation of the waste.
Facility Operating Requirements	Applicable	Regulations pertaining to filling void spaces, disposal unit identification, and facility stabilization and closure are applicable to Clive. Since only low-activity wastes will be disposed at Clive, regulations relating to the segregation of low-activity and high-activity wastes and stability requirements for high-activity wastes do not apply.
Closure and Post-Closure Requirements	Applicable	Closure/post-closure activities must be conducted to ensure long-term stability of the site and isolation of the waste.
Environmental Monitoring	Applicable	Environmental monitoring must provide necessary data to evaluate trends and provide early warning of radionuclide releases.
NRC Standards for Mill Tailings Disposal	Relevant	Should be considered in licensing decision if wastes with concentrations of uranium, thorium, and radium comparable to mill tailings wastes are disposed at Clive site.
EPA Standards		
Cover Requirements	Relevant	Should be considered in licensing decision if wastes with concentrations of uranium, thorium, and radium comparable to mill tailings wastes are disposed at Clive site.
Groundwater Protection	Appropriate	Clive site characteristics should be evaluated to determine if the site characteristics provide adequate protection of groundwater. Experience with Vitro tailings could be a factor in the decision process. The Vitro tailings disposal facility does not include a liner because one was not required by the 1983 EPA standards.

TABLE IV

Site Parameter Values

Parameter	Value	Units
Depth to water table	8.8	m
Distance to nearest surface water	2900	m
Distance to nearest well	1	m
Surface water infiltration rate	0.00124	m/yr
Horizontal velocity of groundwater	2.7	m/yr
Vertical velocity of groundwater	0.02	m/yr
Atmospheric distance to off-site receptor	500	m
Average wind speed	3	m/s
Percent of time blows toward receptor	100	percent
Dust deposition velocity	1.00E-07	m^3/s

Based on information from References 10 and 21.

TABLE V

Exposure Scenarios Modeled

Exposure Scenario	Pathways
Intruder Construction	Direct Gamma-Construction Dust-Construction
Intruder Agriculture	Groundwater to 1-m Well Food Grown On-Site Direct Gamma-Agriculture Dust-Agriculture
Intruder Explorer	Direct Gamma-Maximum Explorer
Maximum Off-Site Individual	Groundwater to Surface Discharge Groundwater to 1-m Well Erosion to River Direct Gamma-Operational Off-Site Atmospheric Transport of Dust Off-Site
On-Site Worker	Direct Gamma-Operational On-Site Dust-Operational On-Site

conservatively assumed 30-yr custodial period and 1,000 years after site closure.

The assumed exposure scenarios for the off-site individual and the agricultural intruder are standard risk assessment scenarios. However, they are certainly conservative, and possibly unrealistic, for the Clive facility. No off-site individual currently lives within 24 km (15 mi) of the site. Because of the arid climate, briny quality of the groundwater that makes it unfit for human consumption, and lack of perennial surface water, it is very unlikely that anyone would choose or be able to live near or engage in agriculture on the Clive site.

Exposure pathway doses were calculated for each of the exposure scenarios shown in Table V. Since, in evaluating pathway doses, the entire radionuclide inventory was postulated to be available for producing exposure via that pathway, summing the pathway doses results in

TABLE VI

Suggested Radionuclide Concentration Limits with all Scenarios Considered

Nuclide	Limiting Exposure Scenario	Concentration Limit (pCi/g)	Does Allowable Concentration Exceed DOT 2,000 pCi/g Limit
Am-241	Offsite Individual	1.7E+02	
Am-243	Offsite Individual	1.7E+02	
C-14	Intruder Agriculture	1.5E+02	
Cd-109	Maximum worker	4.6E+04	Yes
Cm-242	Offsite Individual	1.6E+05	Yes
Cm-242	Offsite Individual	1.6E+02	
Cm-243	Offsite Individual	1.1E+02	
Cm-243	Offsite Individual	6.5E+01	
Cm-244	Offsite Individual	4.5E+02	
Cm-244	Offsite Individual	1.2E+02	
Co-57	Offsite Individual	1.7E+02	
Co-60	Offsite Individual	8.3E+00	
Cs-134	Offsite Individual	1.1E+01	
Cs-137	Offsite Individual	2.8E+01	
Fe-55	Maximum worker	1.8E+06	Yes
H-3	Offsite Individual	2.3E+09	Yes
I-129	Intruder Agriculture	2.5E+03	Yes
Mn-54	Offsite Individual	2.2E+01	
Na-22	Offsite Individual	8.4E+00	
Nb-94	Offsite Individual	1.1E+01	
Ni-59	Maximum worker	6.9E+04	Yes
Ni-63	Offsite Individual	1.5E+07	Yes
Np-237	Offsite Individual	1.7E+02	
Pu-238	Offsite Individual	2.1E+02	
Pu-238	Offsite Individual	1.6E+02	
Pu-239	Offsite Individual	1.7E+02	
Pu-240	Offsite Individual	1.7E+02	
Pu-241	Offsite Individual	1.3E+04	Yes
Pu-241	Offsite Individual	8.6E+01	
Pu-242	Offsite Individual	1.8E+02	
Ra-226	Offsite Individual	2.3E+03	Yes
Ra-226	Offsite Individual	1.1E+01	
Ru-106	Offsite Individual	2.7E+06	Yes
Ru-106	Offsite Individual	8.0E+01	
Sn-113	Offsite Individual	3.2E+03	Yes
Sr-90	Offsite Individual	8.3E+04	Yes
Sr-90	Offsite Individual	8.3E+04	Yes
Tc-99	Intruder Agriculture	1.7E+01	
Th-230	Offsite Individual	2.7E+02	
Th-232	Offsite Individual	5.4E+01	
Th-232	Offsite Individual	7.1E+00	
U-234	Offsite Individual	6.6E+02	
U-235	Offsite Individual	1.1E+02	
U-236	Offsite Individual	7.1E+02	
U-238	Offsite Individual	7.1E+02	
U-Nat.	Offsite Individual	6.8E+02	
Zn-65	Offsite Individual	3.4E+01	

TABLE VII

Suggested Radionuclide Concentration Limits-Unrealistic Scenarios Excluded

Nuclide	Limiting Exposure Scenario	Concentration Limit (pCi/g)	Does Allowable Concentration Exceed DOT 2,000 pCi/g Limit
Am-241	Maximum worker	2.3E+03	
Am-243	Maximum worker	1.9E+03	
C-14	Maximum worker	2.4E+09	Yes
Cd-109	Maximum worker	4.6E+04	Yes
Cm-242	Maximum worker	1.4E+06	Yes
Cm-242	Maximum worker	8.1E+03	Yes
Cm-243	Maximum worker	1.5E+03	
Cm-243	Maximum worker	1.3E+03	
Cm-244	Maximum worker	2.7E+04	Yes
Cm-244	Maximum worker	7.4E+03	Yes
Co-57	Maximum worker	1.9E+04	Yes
Co-60	Maximum worker	3.6E+02	
Cs-134	Maximum worker	1.2E+03	
Cs-137	Maximum worker	5.6E+02	
Fe-55	Maximum worker	1.8E+06	Yes
H-3	Maximum worker	1.4E+11	Yes
I-129	Maximum worker	3.1E+03	Yes
Mn-54	Maximum worker	5.6E+03	Yes
Na-22	Maximum worker	7.8E+02	
Nb-94	Maximum worker	1.6E+02	
Ni-59	Maximum worker	6.9E+04	Yes
Ni-63	Maximum worker	8.5E+08	Yes
Np-237	Maximum worker	2.0E+03	Yes
Pu-238	Maximum worker	1.1E+04	Yes
Pu-238	Maximum worker	8.2E+03	Yes
Pu-239	Maximum worker	9.9E+03	Yes
Pu-240	Maximum worker	1.0E+04	Yes
Pu-241	Maximum worker	8.6E+05	Yes
Pu-241	Maximum worker	1.1E+03	
Pu-242	Maximum worker	1.0E+04	Yes
Ra-226	Maximum worker	1.8E+04	Yes
Ra-226	Maximum worker	1.5E+02	
Ru-106	Maximum worker	1.7E+08	Yes
Ru-106	Maximum worker	1.9E+04	Yes
Sn-113	Maximum worker	7.3E+05	Yes
Sr-90	Maximum worker	5.5E+06	Yes
Sr-90	Maximum worker	5.4E+06	Yes
Tc-99	Maximum worker	6.7E+08	Yes
Th-230	Maximum worker	1.5E+04	Yes
Th-232	Maximum worker	3.3E+03	Yes
Th-232	Maximum worker	1.0E+02	
U-234	Maximum worker	3.7E+04	Yes
U-235	Maximum worker	7.7E+02	
U-236	Maximum worker	3.6E+04	Yes
U-238	Maximum worker	2.8E+04	Yes
U-Nat.	Maximum worker	1.8E+04	Yes
Zn-65	Maximum worker	1.1E+04	Yes

conservatively high estimates of total doses to potentially exposed individuals.

RADIONUCLIDE CONCENTRATION LIMITS

A scenario concentration limit for each nuclide postulated to be present in the waste was calculated for each exposure scenario. An overall concentration limit for each nuclide was then obtained by using the most restrictive (smallest) of the exposure scenario concentration limits. These radionuclide concentration limits for waste disposal at the Clive facility, and the exposure scenarios that provide the bases for these limits, are shown in Table VI. In the vast majority of instances, when all exposure scenarios are considered, the scenario that results in the limiting radionuclide concentration is the maximum exposed off-site individual scenario. For three nuclides, the limiting concentration is determined by the on-site worker scenario, and for three nuclides the limiting concentration is determined by the intruder-agriculture scenario.

However, as already noted, neither the maximum off-site individual scenario nor the intruder-agriculture scenario may be realistic for the Clive facility. If these scenarios are excluded, then the on-site worker scenario becomes the limiting scenario for all radionuclides as shown in Table VII. The corresponding radionuclide concentration limits increase from those shown in Table VI by factors ranging from a few percent to several orders of magnitude.

REFERENCES

1. BAIRD, R.D., ET AL., "Evaluation of the Potential Public Health Impacts Associated with Radioactive Waste Disposal at a Site Near Clive, Utah," prepared for the State of Utah Department of Health, Bureau of Radiation Control, by Rogers and Associates Engineering Corporation, RAE-9004/2-1, June 1990.
2. U.S. NUCLEAR REGULATORY COMMISSION, "Licensing Requirements for Land Disposal of Radioactive Waste (10 CFR Part 61)," Federal Register, Vol. 47, No. 248, pp 57463-57477, December 27, 1982.