PERFORMANCE ASSESSMENT OF A MIXED WASTE DISPOSAL FACILITY LOCATED IN A HUMID ENVIRONMENT

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ABSTRACT

The operating history of the disposal facility is briefly reviewed. The methodology used to assess the performance of the facility is described. The environmental pathways modeled are cursorily characterized and potential radiation exposure scenarios are defined. Important site and waste characteristics are presented. Model projections are compared to observation and the projected radiological and chemical risks are summarized.

BACKGROUND

A rural waste disposal site was used for the disposal of radioactive wastes with hazardous constituents from facilities operated by a university in the Midwest from 1964 through 1982. The site is divided into two disposal areas were licensed and operated as separate low-level radioactive waste disposal facilities. The actual area occupied by waste disposal units at each facility is approximately one acre. These disposal areas are within the property owned by the university and licensed for radioactive waste disposal, which totals approximately 23 acres.

The radioactive wastes disposed at the site included solid wastes such as waste paper, resins, and animals; aqueous wastes; and liquid scintillation fluids, including organic solvents. Containers for the wastes included paper cartons, cardboard boxes, bottles, jugs, vials, and metal drums. The wastes were disposed in trenches approximately 8 feet deep, 2 feet wide, and from 10 to 100 feet long. A map of the site and the groundwater elevations at the site are shown in Fig. 1.

PATHRAE ASSESSMENT METHODOLOGY

The PATHRAE computer model program was used for projecting radiological and hazardous contaminant transport, exposure to contaminants, and human risk to provide an accepted, broadly applicable method for all pathways (1,2).

ENVIRONMENTAL PATHWAYS

Several environmental pathways for human exposure to radioactive and hazardous chemical wastes were evaluated in the risk assessment. These include: groundwater transport to a surface stream, groundwater transport to existing and potential water wells, consumption of food grown onsite, and direct radiation exposure to both occasional trespassers and assumed intruder residents.

Since control of the site cannot be assured for an unlimited time, intrusive use of the site is assumed after a period of control. The principal hazard to noninvasive intrusion, though extremely small, is exposure to gamma radiation emanating from the site. Another pathway considers invasive intrusion, which includes digging into the waste while building a house and installing a well. The food pathway projects the health effects of consuming food grown directly in contaminated soil. The natural biointrusion pathway involves the consumption of crops whose roots have penetrated into previously undisturbed waste. The two atmospheric pathways considered are onsite and offsite dust inhalation. Values of parameters used to characterize human uptakes and exposures are summarized in Table I.

EXPOSURE SCENARIOS

The contaminant transport pathways described previously were combined to describe four commonly accepted exposure scenarios.

The site may be explored from time to time by a transient visitor. This explorer scenario is traditionally represented by the noninvasive direct gamma radiation exposure pathway, with the cover material over the waste acting as a shield. A more invasive onsite scenario considers a reclaimer constructing a house and well, then living onsite while eating food grown onsite and drinking water from the well.

Offsite scenarios address exposures to a downstream population using water contaminated by groundwater releases from the site and the possibility that a farmer might plant crops on the site in future years and incur doses from both direct exposures from noninvasive intrusion and from using the crops (either directly as food or as feed for livestock).

The use of pathways in the four scenarios is presented in Table II.

SITE CHARACTERISTICS

The site-specific parameters defining the transport of contaminants from the two facilities along various environmental pathways are presented in Table III.

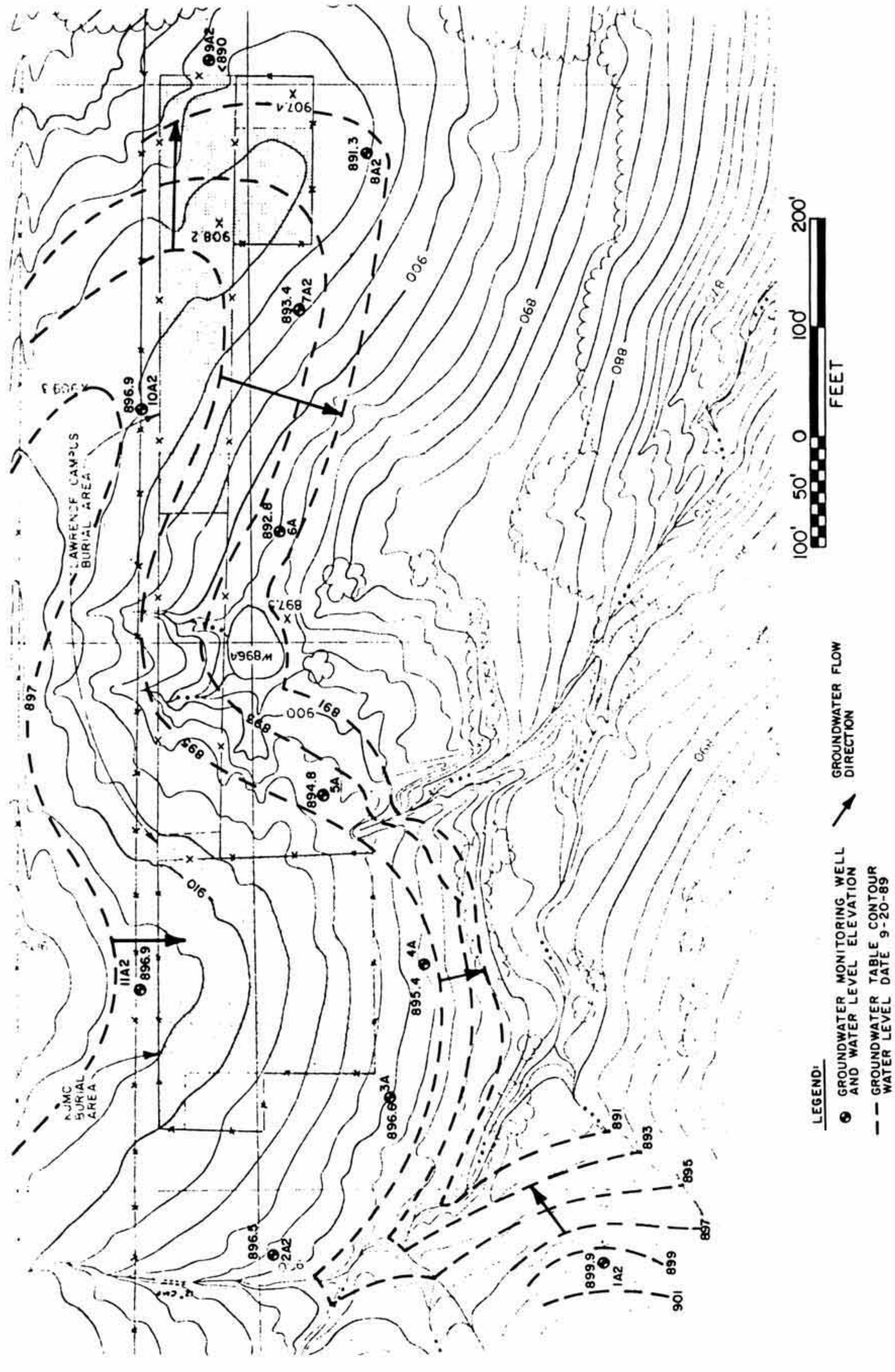

Fig. 1. Surface and groundwater profiles.

TABLE I

Ingestion, Inhalation, and Exposure Parameter Values

Medium	Parameter	Exposure or Value
Groundwater	Drinking water consumption	370 L/yr
	Water percolation rate	3.3 cm/yr
	Irrigation rate	0.015 L/sq m-hr
	Fraction of year crops are irrigated	0.40
	Aquifer properties	
	porosity	0.20
	density	2.29 g/cu cm
	water velocity	5 m/yr
	Saturated thickness of aquifer	1.5 m
	Concentration	calculated
Surface water	Creek flow rate	4.0E+06 cu m/yr
	Drinking water consumption	370 L/yr
	Concentration	calculated
Soil	Concentration	calculated average for onsite resident
	Ingestion	Not assessed directly
	Density	1.6 g/cu cm
	Direct gamma exposure factor	1.0
	Dust loading in air	1.0E-07 kg/cu cm
	Fraction of year exposed to dust	1.0
Plants grown in contaminated soil	Concentration in plants	calculated
	Fraction of diet supplied by contaminated food	0.50
	Leafy vegetable uptake	18 kg/yr
	Produce uptake	176 kg/yr
	Animal forage production rate	0.67 kg/sq m-yr
	Milk uptake	112 L/yr
	Meat uptake	85 kg/yr
Air	Dust resuspension rate	1.0E-07 cu m/s
	Fraction of time wind blows toward receptor	1.0
	Average wind speed	3 m/s
	Distance to atmospheric receptor	200 m
	Particulate deposition velocity	0.01 m/s
	Breathing rate	8,000 cu m/yr
	Pasquill stability class	D

TABLE II

Summary of Pathways Comprising Each Post-Closure Scenario

Pathway	Used in Scenario
Groundwater to well	Reclaimer
Groundwater to stream	Surface Water User
Erosion	Surface Water User
Natural biointrusion	Offsite Farmer
Onsite food	Reclaimer
Noninvasive intrusion	Explorer
Invasive intrusion	Reclaimer
Onsite dust inhalation	Reclaimer
Offsite dust inhalation	Offsite Farmer

TABLE III

Parameters Defining Contaminant Transport Along Selected Environmental Pathways

	Value	
Parameter	Area #1	Area #2
Groundwater flow rate (m/yr)	5	5
Porosity of sandstone	0.2	0.2
Density of sandstone (kg/cu m)	2,291	2,291
Distance from trench bottom to groundwater (m)	0	0
Distance from source to well (m)	15	25
Length of well screen (m)	1.5	1.5
Distance to surface discharge (m)	30	170
Creek flow rate (cu m/yr)	4.0E+06	4.0E+06
Longitudinal dispersivity (m)	4.8	4.0
Lateral dispersion coefficient (sq m/yr)	0.16	0.16
Amount of water percolating through water (m/yr)	3.3E-03	3.3E-03
Distance to offsite receptor (m)	200	200
Wind speed (m/sec)	3	3

WASTE CHARACTERISTICS

The wastes of concern buried at the disposal site were generated by both hospitals and university research laboratories. The waste itself is composed of trash, carcasses, ion exchange resins, spent scintillation solvents, and other organic and aqueous wastes. The majority of this waste is contaminated with radioactive materials commonly associated with the medical treatment and research fields.

The bulk of the information used to compile the radioactive inventories consisted of records kept by the university, as required by their radioactive materials license

TABLE IV

Radioactive Inventories

Nuclide	Number of Burials	Inventory (mCi) As Buried	Inventory (mCi) As of 10/1/89
AREA #1			
Buried Nuclides			
H-3	86	9.2E+03	5.0E+03
C-14	89	1.5E+02	1.4E+02
Na-22	30	5.7E+00	9.2E-02
Cl-36	41	6.6E+00	5.3E+00
Sr-90	3	5.0E+02	3.0E+02
Tc-99	5	1.0E+01	1.0E+01
Cd-109	32	1.6E+01	5.9E-02
Ra-226	2	2.2E-02	2.2E-02
Nuclide Produced by Decay of Sr-90			
Y-90	---	---	3.0E+02
Nuclides Produced by Decay of Ra-226			
Pb-214	---	---	2.2E-02
Bi-214	---	---	2.2E-02
Pb-210	---	---	2.2E-02
Po-210	---	---	2.2E-02
AREA #2			
Buried Nuclides			
H-3	82	1.2E+04	6.0E+03
C-14	79	1.8E+02	1.8E+02
Na-22	30	3.0E+00	2.2E-01
Cl-36	6	1.5E-01	1.4E-01
Co-60	30	1.4E+00	1.8E-01
Kr-85	1	4.8E+01	2.2E+01
Sr-90	8	2.9E-01	1.7E-01
Tc-99	1	1.8E-02	1.8E-02
Ba-133	1	1.5E-01	6.9E-02
Cs-137	13	9.9E-01	6.3E-01
Eu-152	4	1.6E-01	8.3E-02
Pb-210	8	3.9E-01	2.6E-01
Ra-226	7	3.0E-01	2.9E-01
Th-232	1	1.0E-03	1.0E-03
U-238	1	1.3E-02	1.2E-02
Nuclide Produced by Decay of Sr-90			
Y-90	---	---	1.7E-01
Nuclide Produced by Decay of Cs-137			
Ba-137	---	---	6.3E-01
Nuclides Produced by Decay of Ra-226			
Pb-214	---	---	2.9E-01
Bi-214	---	---	2.9E-01
Pb-210	---	---	2.9E-01
Po-210	---	---	2.9E-01
Important Nuclides Produced by Decay of Th-232			
Ra-228	---	---	1.0E-03
Ac-228	---	---	1.0E-03
Th-228	---	---	1.0E-03
Ra-224	---	---	1.0E-03
Pb-212	---	---	1.0E-03
Bi-212	---	---	1.0E-03
Tl-208	---	---	1.0E-03
Nuclides Produced by Decay of U-238			
Th-234	---	---	1.2E-02
Pa-234m	---	---	1.2E-02

TABLE V

Assumed Hazardous Inventories

Chemical Waste	Assumed Buried Mass (kg) Area #1	Area #2
Acetonitrile	1	1
Ammonium Ion	1	---
Benzene	540	540
Chloroform	60	60
1,2-Dichloroethane	12	12
Dichloromethane	3200	3200
1,2-Dioxane	4300	4300
Ethyl acetate	1	---
Ethyl alcohol	1	---
Ethyl benzene	4	4
Methanol	40	40
Molybdenum	1	---
Naphthalene	10	---
Phenol	10	---
Sulfate	1	---
Toluene	8500	8500
Trichloroethylene	260	200
Xylene	500	500

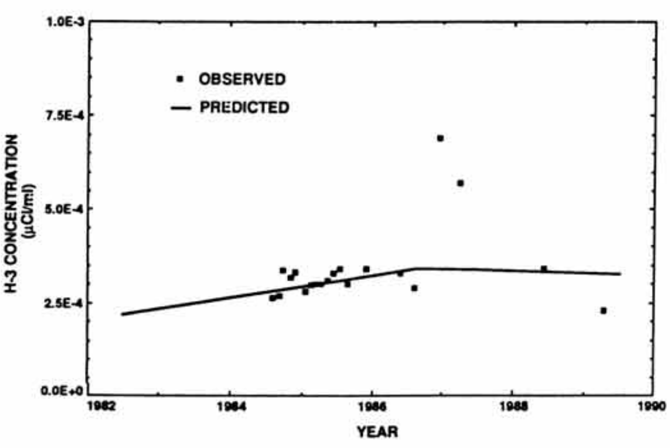

Fig. 2. Projected and observed Tritium concentrations vs. time.

agreements with the State. Records detailing the hazardous constituents of the two areas are substantially less complete, and several assumptions about the makeup of the inventory had to be made. Table IV presents the radiological inventories and Table V presents the assumed hazardous inventories in the disposal facility.

PROJECTIONS COMPARED TO OBSERVATIONS

The PATHRAE projections of the H-3 concentrations in groundwater in one well were then compared with actual observed H-3 concentrations for that well as shown in Fig. 2. The results provided reasonable assurance that the representative of the groundwater pathway, facility features, and waste characteristics described is realistic for the disposal area.

RESULTS OF RISK ASSESSMENTS

The potential for adverse impacts to the health of populations surrounding the disposal facility were evaluated. These results are summarized in Tables VI and VIII. The radiological impacts appear to exceed the NRC's limit of 25 mrem/yr if it were licensed under 10 CFR 61 (3). Further, they clearly would not satisfy EPA's groundwater protection requirement of 4 mrem/yr. The risks associated with migrating hazardous constituents are very large relative to typically accepted risks (i.e., 10^{-6} HE/yr).

TABLE VI

Summary of Chemical-Induced Risks (HR/yr)

Pathway	Area #1	Peak Year	Area #2	Peak Year	Scenario
Groundwater to well	2.7E-02	2082	5.1E-02	2093	Reclaimer
Groundwater to stream	1.3E-06	2482	1.2E-06	2093	Surface Water User
Natural biointrusion	---	---	2.4E-03	1989	Offsite Farmer
Onsite food	4.0E-04	1989	1.6E-03	1989	Reclaimer
Onsite dust inhalation	2.1E-08	1989	8.3E-08	1989	Reclaimer
Offsite dust inhalation	6.1E-09	1980	5.0E-09	1989	Offsite Farmer
Maximum dose rate	2.7E-02	2082	5.1E-02	2083	Reclaimer

TABLE VII

Summary of Radiological Dose (mrem/yr)

Pathway	Area #1	Peak Year	Area #2	Peak Year	Scenario
Groundwater to well	2.0E+1	1989	4.1E+01	1989	Reclaimer
Groundwater to stream	2.6E-02	2082	2.2E-02	2012	Surface Water User
Erosion	9.1E-04	2982	1.2E-04	2482	Surface Water User
Natural biointrusion	---	---	5.1E-01	1989	Offsite Farmer
Onsite food	1.1E-02	1989	3.2E-01	1989	Reclaimer
Noninvasive gamma	1.7E+00	2982	1.4E-01	2489	Explorer
Invasive gamma	2.6E+00	2982	5.4E-01	1989	Reclaimer
Onsite dust inhalation	9.5E-05	1989	3.8E-05	1989	Reclaimer
Offsite dust inhalation	2.9E-04	1989	4.5E-05	1989	Offsite Farmer
Maximum dose rate	2.0E+01	1989	4.2E+01	1989	Reclaimer

REFERENCES

1. MERRELL, G.B., V.C. ROGERS, AND M.K. BOLLENBACHER, "The PATHRAE-RAD Performance Assessment Code for the Land Disposal of Radioactive Wastes," Rogers and Associates Engineering Corporation, RAE-8511-28, August 1987.
2. ROGERS, V.C., G.B. MERRELL, AND M.K. BOLLENBACHER, "The PATHRAE-HAZ Performance Assessment Code for the Land Disposal of Hazardous Chemical Wastes," Rogers and Associates Engineering Corporation, RAE-8511-29, August 1987.
3. 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.