ALTERNATIVES FOR DEFENSE WASTE SALT DISPOSAL[a]

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ABSTRACT

Alternatives for disposal of decontaminated high-level waste salt at Savannah River were reviewed to estimate costs and potential environmental impacts for several processes. In this review, the reference process utilizing intermediate-depth burial of salt-concrete (saltcrete) monoliths was compared with alternatives including land application of the decontaminated salt as fertilizer for SRP pine stands, ocean disposal with and without containment, and terminal storage as saltcake in existing SRP waste tanks. Discounted total costs for the reference process and its modifications were in the same range as those for most of the alternative processes; uncontained ocean disposal with truck transport to Savannah River barges and storage as saltcake in SRP tanks had lower costs, but presented other difficulties. Environmental impacts could generally be maintained within acceptable limits for all processes except retention of saltcake in waste tanks, which could result in chemical contamination of surrounding areas on tank collapse. Land application would require additional salt decontamination to meet radioactive waste disposal standards, and ocean disposal without containment is not permitted in existing U.S. practice. The reference process was judged to be the only salt disposal option studied which would meet all current requirements at an acceptable cost.

INTRODUCTION

The defense waste salt at the Savannah River Plant (SRP) is an alkaline waste product resulting from neutralizing the high-level waste produced during processing irradiated nuclear fuel. Neutralizing the high-level waste separates it into two components, sludge and salt supernate. The sludge component consists mainly of insoluble iron, aluminum, and manganese hydroxides and contains most of the fission product [principally strontium (Sr-90)] and actinide radioactivity; the sludge will be immobilized as a glass form for eventual emplacement in a geologic repository.[1,2] The salt supernate consists of a solution containing sodium nitrate, nitrite, hydroxide, and aluminate; it will be processed to remove fission product cesium (Cs-137) and residual other radionuclides for eventual disposal as a low-level waste. The reference process for disposal of "decontaminated" salt is intermediate-depth burial as salt-concrete (saltcrete) monoliths in underground trenches.[2,3] The purpose of this review is to compare costs and environmental impacts of this reference process and its modifications with various other alternatives for disposal of the waste salt.

Two principal approaches exist for disposal of the decontaminated salt. The first, represented by the reference process, involves isolation from the biosphere for very long times, allowing reentry to the environment only very slowly. The second approach involves rapid dispersion in potentially beneficial (by use as fertilizer) or neutral ways (such as ocean disposal without containment). Hazards associated with residual radioactivity and chemical constituents of the salt depend on the disposal method. The radioactivity is a relatively minor problem in the first approach, because of the low concentration of radionuclides involved; chemical hazards due to the large quantities of nitrate/nitrite present can be more severe. For the dispersion methods of disposal, the salt presents a minimum chemical hazard, but could be perceived as a significant radioactivity pollutant.

SALT DISPOSAL PROCESSES

Saltcrete Monoliths for Intermediate Depth Burial

Chemical composition of the salt supernate is given in Table I. Expected concentrations of major radionuclides in the decontaminated salt solution are shown in Table II. The salt may be decontaminated by in-tank precipitation of cesium (principally Cs-137) as tetraphenylborate and by adsorption of residual Sr-90 and actinides on sodium titanate.[4] Alternatively, the Cs-137 may be removed by ion-exchange methods. In one possible modification, residual technicium (Tc-99) may also be removed by ion-exchange processes. The salt will be aged at least 15 years after reactor discharge to allow decay of ruthenium-106 (halflife 1-y) before final disposal.[2,3] The radionuclide concentrations in Table II were derived from laboratory analyses of actual SRP wastes and from calculated fission product levels in SRP fuels.

In the reference disposal process, the decontaminated salt solution is mixed with concrete and poured to form saltcrete (or soil/saltcrete*) monoliths in

*Soil/saltcrete is an alternative waste form being developed for lower water permeability than the reference saltcrete. Compositions of the two waste forms are as follows:

	Saltcrete	Soil/Saltcrete
Cement	51.1 wt %	24.5 wt %
Salt	15.5	10.6
Water	33.0	22.5
Pozzolith	0.4	0.2
Soil	-	42.2

[a] The information contained in this article was developed during the course of work under Contract No. DE-AC09-76SR00001 with the U.S. Department of Energy.

Table I. Chemical Composition of Decontaminated Salt Solution

Component	Composition, wt %
H_2O	68.
$NaNO_3$	15.6
$NaNO_2$	3.9
NaOH	4.2
Na_2CO_3	1.7
$NaAl(OH)_4$	3.6
Na_2SO_4	1.9
NaF	0.06
NaCl	0.12
Na_2SiO_3	0.04
Na_2CrO_4	0.05
NaHgO(OH)	1.7×10^{-6}
$NaAg(OH)_2$	1.4×10^{-7}
Na_2MoO_4	0.008
KNO_3	8.6×10^{-6}
$CaSO_4$	2.5×10^{-4}
$Na_2C_2O_4$	0.31
Na_3PO_4	0.13
NH_4NO_3	6.7×10^{-6}
$Na[B(C_6H_5)_4]$	0.06
Other salts	0.20

Table II. Concentrations of Major Radionuclides in Decontaminated Salt Forms†

Isotope ($T_{1/2}$,yrs)	Salt Solution[a] (nCi/g)	Salt (nCi/g)	Saltcrete[b] (nCi/g)	Soil-Saltcrete[b] (nCi/g)
H-3 (12.3)	10	40	6	4
C-14 (5730)	0.009	0.03	0.005	0.003
Co-60 (5.3)	0.2	0.7	0.1	0.07
Ni-59 (80,000)	0.0002	0.0007	0.0001	0.0001
Ni-63 (100)	0.02	0.07	0.01	0.007
Se-79 (65,000)	0.3	1	0.2	0.1
Sr-90 (29)	0.7	3	0.5	0.3
Y-90* (3.1 hr)	0.7	3	0.5	0.3
Tc-99 (2.1×10^5)	40[c]	100[c]	20[c]	10[c]
Ru-106 (1.0)	40	100	20	10
Rh-106* (2.2 hr)	40	100	20	10
Sb-125 (2.7)	9	30	5	3
Te-125m* (5.8 d)	0.2	0.7	0.1	0.07
Sn-126 ($\sim 10^5$)	0.2	0.5	0.08	0.05
Sb-126m* (19 min)	0.2	0.5	0.08	0.05
Sb-126* (12.5 da)	0.02	0.05	0.008	0.005
I-129 (1.7×10^7)	0.2[d]	0.7[d]	0.1[d]	0.07[d]
Cs-134 (2.06)	0.1	0.3	0.05	0.03
Cs-137 (30.2)	20	70	10	7
Ba-137m* (2.5 min)	20	60	9	6
Pm-147 (2.6)	4	10	2	1
Sm-151 (93)	2	7	1	0.7
Eu-154 (8.2)	1	3	0.5	0.3
Eu-155 (4.76)	0.3	1	0.2	0.1
Pu-238 (87.7)	0.05	0.2	0.03	0.02
Pu-239 (2.4×10^4)	0.0005	0.002	0.0003	0.0002
Pu-241 (14.4)	0.04	0.1	0.02	0.01
Am-241 (433)	0.2	0.5	0.08	0.05
All TRU (except Pu-241)	0.2	0.7	0.1	0.07

†15 years after reactor discharge of spent fuel producing the waste.

*Daughter of preceding radionuclide.

[a] Assumes 5.5 M salt (1.25 sp gr).

[b] Assumes 0.155 g salt/g saltcrete and 0.106 g salt/g soil-saltcrete.

[c] Tc-99 removal would reduce these to 10% of the values shown.

[d] Actual concentration is expected to be less than shown because all iodine is assumed to be in the salt and losses during chemical separations are not included.

underground trenches.[3] The saltcrete formulations are mixed in commercially available high-shear mixers and pumped directly to the burial trenches; set time is about 5 hours. For the saltcrete waste form, the burial trenches would be lined and capped with low permeability clay to inhibit leaching of chemical and radionuclide constituents of the saltcrete to the groundwater. The alternative soil/saltcrete form would eliminate the need for clay liners.

The saltcrete landfill would be constructed to meet U.S. Department of Energy, Environmental Protection Agency, and other applicable criteria for chemical and low-level radioactivity waste disposal. The saltcrete monoliths, each typically 125-ft long, and 25-ft thick with trapezoidal cross section 40-ft wide at top and 16-ft wide at the bottom, would occupy an onsite area of about 100 acres. The monoliths would be located at least 3 meters above the historic high water table at the site and be covered with at least 5 meters of soil overburden. Compressive strength of the reference saltcrete is about 700 psi, adequate to support soil overburden and packing equipment.

Startup of the salt disposal operation was assumed to begin in 1986. At a processing rate of 10 gallons salt solution per minute, the 100 million gallons of 15-year aged salt supernate projected to have been produced through year 2001 would be worked off in 31 years.

Costs

Base cost estimates derived from data developed by the Du Pont Engineering Department for the reference saltcrete burial process include a $23 million capital charge and $7 million/year operating expense; Tc-99 removal would cost an additional $13 million capital and $2 million/year operating expense. Use of the soil/saltcrete form would increase capital charges moderately to $24 million (without Tc-99 removal), but reduce operating costs to about $5 million/year, mainly because of elimination of trench liners. Cost breakdowns are as follows:

Capital	10^6 $	Operating	10^6 $/yr
Saltcrete in Clay-Lined Trenches (Reference Process)			
Building	3	Trenches	3
P, G, & S*	4	Cement	2
Pipeline	6	Manpower	2
Process Equipment	3		
Site Preparation	7	Subtotal	7
Subtotal	23	Tc-99 Removal	2
Tc-99 Removal	13	Total	9
Total	36		
Soil/Saltcrete in Unlined Trenches			
Building	3	Trenches	1
P, G & S*	4	Cement	2
Pipeline	6	Manpower	2
Process Equipment	3		
Site Preparation	8	Total	5
Total	24		

*Power, General, and Support Facilities

Environmental Effects

The reference process for salt disposal by burial as saltcrete monoliths is a low-level waste disposal procedure designed to meet regulations for radioactive waste disposal by the Nuclear Regulatory Commission (NRC)[5] and guidelines for chemical waste disposal by the Environmental Protection Agency (EPA)[6-8] and the South Carolina Department of Health and Environmental Control (SCDHEC)[9]. The NRC low-level waste regulations require (1) protection of the general public from release of radioactivity to the environment, (2) protection of individuals from inadvertent intrusion after institutional controls on the site are removed, and (3) protection of occupational workers during site operations. The first requirement limits radioactive materials released to the environment in groundwater, surface water, air, soil, plants, and animals to con-

centrations that will not result in annual doses to individuals of the general public exceeding 25 mrem whole body, 75 mrem thyroid, and 25 mrem any other organ; more generally, the radioactivity releases are required to be as low as reasonably achievable. Compliance with this requirement for decontaminated salt disposal is being demonstrated in the modeling and experimental studies now in progress.[10]

Compliance with the second requirement, e.g. inadvertent intruder protection, was determined by comparison of radionuclide concentrations in the waste form with limiting concentrations for wastes in categories designated Classes A, B, and C. Radionuclide limits for each category are specified so as to prevent an annual radiation exposure greater than 500 mrem to an inadvertent intruder. Class A (segregated) wastes can contain possibly unstabilized material with radionuclides limited to concentrations ensuring intruder protection within the required 100-year time of institutional site control. Class B (stabilized) waste must be treated so as to be structurally stable for 300 years. Class C intruder waste must be structurally stable and also provided with special protection against inadvertent intrusion (by deeper burial or other barrier) for 500 years. Comparison of the radionuclide content of decontaminated salt with the waste classification limits is shown in Tables III-A and III-B for long-lived and short-lived radioactivities, respectively. The radionuclide content of the salt in saltcrete form is less than the limiting concentrations for all three waste categories. The saltcrete form is considered to provide the stabilization needed for Class B waste, and the depth of burial of the saltcrete monoliths should provide the protection against inadvertent intrusion specified for Class C waste.

Table III. Comparison of Radionuclide Concentrations in Saltcrete with NRC Low-Level Waste Disposal Categories

Radionuclide	Concentration in Saltcrete (μCi/cc)	Concentration Limit (μCi/cc)
A. Long-Lived Activities		Class A
C-14	1×10^{-5}	0.8
Ni-59	2×10^{-7}	22 (in activated metal)
Tc-99	0.04[a]	0.3
I-129	0.002	0.008
TRU (except Pu-241)	0.0002	0.019 (equiv. to 10 nCi/g)
Pu-241	4×10^{-5}	665 (equiv. to 350 nCi/gm)

B. Short-Lived Activities		Class A	Class B	Class C
Any, half life <5 y	0.09	700	*	*
H-3	0.01	40	*	*
Co-60	2×10^{-4}	700	*	*
Ni-63	2×10^{-5}	3.5	70	700
Sr-90	0.002	0.04	150	7000
Cs-137	0.04	1	44	4600

*No limit.

[a] Tc-99 removal would reduce concentration to 10% of value shown.

Compliance with the third NRC requirement, occupational exposures within prescribed limits, would be based on existing SRP practice.

Control of chemical hazards of waste salt disposal is governed by EPA and SCDHEC regulations[6-9]. These regulations require that concentrations of chemical contaminants in groundwaters at waste site boundaries not exceed limits specified in National Interim Primary Drinking Water Regulations.[11] Constituents of primary concern and their prescribed limits are nitrate/nitrite (as nitrogen) 3.5 mg/L and mercury 0.002 mg/L. Solid wastes that could potentially contaminate groundwaters beyond such limits must be disposed of in landfills meeting specified requirements including protective (low permeability) clay caps and liners, and effluent monitoring systems.

The rate of release of salt from the saltcrete monoliths is the key factor in the control of chemical contamination of ground waters. Salt release can occur by two processes (1) dissolution by infiltrating rain water penetrating the protective clay cap and permeating through the waste form and (2) leaching by diffusion to waste form surfaces. Quantities of salt released by these mechanisms are being determined by computer modeling and field tests to guide the design of the saltcrete landfill.[3] The landfill will be constructed to meet the requirements for control of nitrogen as nitrate/ nitrites in the groundwaters. Under these conditions, mercury contamination would not be limiting. Development of the permeation resistant soil-saltcrete waste form will simplify design of a landfill meeting acceptable standards.

Land Application of Decontaminated Salt-Supernate

Application of decontaminated salt-supernate to the forested areas of the Savannah River Plant site has been proposed as an alternative to the reference saltcrete disposal process. Salt solution applied at a rate of 500 gallons per acre would provide approximately 200 pounds per acre of nitrogen as fertilizer for vegetative growth. The solution would be applied using conventional agricultural equipment, with access to the pine forests provided along rows removed for pulpwood during the thinning process. In a representative scenario, ten applications at 3-year intervals over 20,000 acres (about 1/10 the Savannah River Plant area) would dispose of 100 million gallons of salt supernate within 30 years. Calculations indicate the SRP forest could readily assimilate the expected 40 million pounds of nitrogen present as nitrate and nitrite in the supernate, but effects of potentially toxic chemical contaminants (such as boron), as well as the residual radionuclides, must be evaluated. Additional decontamination ("polishing") of the salt to reduce residual Cs-137, Sr-90, and Tc-99 concentrations remaining after in-tank processing might also be necessary to achieve acceptable radiation levels for disposal using land application. For the cost and environmental impact evaluations, additional decontamination to reduce these radionuclides by factors of 100, 10, and 10, respectively, were assumed.

Costs

Costs for land application of the decontaminated salt, including process equipment for additional polishing, were estimated to total $36 million capital and $5 million/year operating expenses. Cost breakdowns are as follows:

Capital	10^6 $	Operating	10^6 $/yr
Field Eqpt and Bldg	1	Material	2
Process Eqpt	22	Manpower	3
Buildings	4		
P,G,&S*	3	Total	5
Pipeline	6		
Total	36		

* Power, General, and Support Facilities.

Environmental Effects

Land application utilizes the decontaminated salt as a chemical fertilizer. There exist at present no 'de minimis' standards for classification of a nuclear waste as non-radioactive[5] so that acceptable radiological impacts of such use must be established by comparison with other criteria, such as background radiation and fallout from nuclear weapons testing, EPA drinking water standards, and NRC low-level waste disposal regulations.

Radionuclide content of soil to which decontaminated and polished salt solution is applied at a rate of 500 gal/acre would be about 320 pCi/g soil (assumed 5-cm depth) decaying by a factor of five after 30 years. The maximum radiation dose to an individual continuously occupying the area over one year's time would be about 650 mrem, mainly due to direct gamma radiation. Integrated effects of multiple applications at 3-year intervals have not been established, but direct exposures may not be greatly increased because of infiltration into deeper soil layers. The maximum radiation dose is about equal to NRC limits for occupational exposures, and exceeds typical background and weapons fallout exposures (100 mrem/yr). Institutional control of the disposal site providing restricted access for extended time periods, as specified for low-level waste burial sites, might be required to diminish these direct radiation exposures. Radiation doses from drinking water and foodchain sources incurred by ingestion of radionuclides retained onsite would also be low after the 100-year period of institutional control. Radiation doses from offsite drinking water and foodchain sources, within the period of institutional control, must be evaluated by modeling studies.

The pine forests treated with the decontaminated supernate would have to be monitored for uptake of radionuclides, and, depending on uptake levels, restrictions on the tree utilization could be required during the period of institutional control.

Chemical impacts of land application of decontaminated supernate should be small. Possible contamination of groundwater with nitrogen (nitrate/nitrite) would be comparable to that from conventional agricultural practice and would be limited to the few years required for the contaminated groundwater to migrate to surface outcrops. Subsequent dilution in surface waters would reduce contaminant levels to well below drinking water standards.

Ocean Disposal of Decontaminated Salt

Ocean dumping of decontaminated salt solution has been considered as a substitute for the reference disposal process because of possible cost savings and reduced environmental impacts. Ocean dumping has been utilized by many countries, including the United States, for disposal of low-level wastes.[12] However, most of the low-level wastes, including soluble and insoluble chemical materials, have been packaged prior to disposal. In recent years, ocean dumping of low-level wastes has come under the supervision of international agencies devoted to prevention of chemical and radioactive pollution of the marine environment. With International Atomic Energy Agency (IAEA) assistance, the Nuclear Energy Agency (NEA) supervises for NEA member countries the dumping of radioactive materials in the Northeast Atlantic. The London Dumping Convention (LDC)[13], convened in 1972 and ratified by 43 countries including the U.S. by 1979, specifies requirements for ocean transport and disposal of wastes, with IAEA responsible for defining limits on radioactivity in materials suitable for dumping. The LDC rules permit wastes contaminated with trace amounts of naturally-occurring radionuclides to be dumped without containment, but otherwise require low-level waste to be stabilized and contained.

Between 1946 and 1970, the U.S. dumped packaged radioactive wastes containing 79.5 kCi of radioactivity into the Atlantic Ocean and 15 kCi into the Pacific Ocean. In 1970, the U.S. discontinued ocean dumping in favor of land burial of the low-level wastes. EPA administers a Permit Program for ocean disposal of low-level waste, specifying isolation and containment criteria, but since 1970, no permits to dump have been requested or issued. Recent legislative initiatives approved by a House Subcommittee reauthorized the ocean dumping permit program, and EPA is working on new regulations.[14] According to an early draft, the proposed revisions will permit limited ocean dumping of radioactive wastes, but only with containment.

For packaged disposal, SRP decontaminated salt solution would be mixed with cement to form saltcrete cast into 55-gal drums. Assuming the same composition as for land burial, about 150 million gal of saltcrete would be made. The waste drums would be transported by truck to a dock at the Savannah River, transferred to barges, and pulled by tugboat down the river to a specified dumping area in the Atlantic Ocean.

For unpackaged disposal, two methods of transporting SRP salt to the ocean appear feasible. In one method, decontaminated salt solution would be pumped to a large cargo tank trailer for transport to a Savannah River barge capable of carrying the salt solution to sea. A second method is to pump the salt solution through a doubly contained pipeline to the barge at the river. Truck transport, although much less expensive, would require major study to determine its acceptability. The salt solution would be dumped from the barge directly into the ocean without containment. The dispersion and dilution capacity of the ocean would be depended upon to prevent undesirable concentrations of chemicals or radionuclides in the marine environment.

Costs

Costs for ocean disposal of salt packaged as low-level waste were estimated to total $23 million capital and $10 million/year operating expenses. Costs for ocean disposal of salt solution without containment were estimated to total $4 million capital for truck transport and $62 million capital for pipeline transport of salt solution to Savannah River barges. Operating charges were estimated $3 million/year in each of the latter cases. Cost breakdowns are as follows:

Capital	10^6 $	Operating	10^6 $/yr
Packaged Salt to Barge by Truck			
Building	5	Cement, Drums	3
P,G,&S*	5	Manpower	4
Pipeline	1	Tugs and Crew	1
Process Equipment	5	Channel Maintenance	2
Trucks, Terminals	2	Total	10
Barges (5)	5		
Total	23		
Unpackaged Salt to Barge by Tank Trailer			
Trucks, Pumps, Terminals	2	Tug and Crew	0.5
Barges (2)	2	Manpower	0.5
Total	4	Channel Maintenance	2.0
		Total	3.0
Unpackaged Salt to Barge by Pipeline			
Pipeline	60	Tug and Crew	0.5
Barges (2)	2	Manpower	0.5
Total	62	Channel Maintenance	2.0
		Total	3.0

* Power, General and Support Facilities.

Environmental Effects

The environmental consequences of ocean disposal of decontaminated salt are expected to be minor, because the amount of radioactivity in the salt solution (100 kCi) is small compared to the radioactivity associated with previous disposal practice (700 kCi, in North Atlantic 1967-1980),[12] with fallout from nuclear weapons testing (6.6×10^5 kCi, 1979), or with natural radioactivity in the oceans (4.7×10^7 kCi). However, it would also be necessary to evaluate the environmental consequences of possible spills in the SRP and barge transport systems.

The radionuclide contents of decontaminated salt (without Tc-99 removal) are well within the LDC limits on radioactivity for ocean dumping low level wastes, as shown in Table IV. The LDC limits apply, however, only to packaged waste. Dose-to-man analyses of radioactivity exposures through the marine food chain would be required to certify acceptability of the ocean disposal of unpackaged salt.

Table IV. Comparison of Radionuclides in Decontaminated Salt Solution with London Dumping Convention (LDC) Limits for Ocean Disposal

	Salt Solution (μC/g)	LDC Limits (μC/g)
Alpha (TRU)	0.0003	1.0
Long-Lived Beta/Gamma (Tc-99)	0.03	100
Tritium and Short/Lived Beta/Gamma (Sr-90, Y-90, Ru-106, Rh-106, Sb-125, Cs-127, Ba-137m, Pm-147, Sm-151, Eu-154)	0.14	1×10^6

Decontaminated Saltcake in SRP Waste Tanks

The possibility was also investigated of disposing of the decontaminated salt solution as wet saltcake in the existing SRP waste tanks. In this alternative, the decontaminated salt solution would be concentrated in evaporators and the concentrate would be transferred to existing waste storage tanks and allowed to cool. Salt would crystallize from the cooling solution and deposit in the tank as damp saltcake containing 78 wt % salt. The remaining supernate would be returned to evaporators for further concentration and crystallization. The evaporate would be condensed, decontaminated by ion exchange if necessary, and discharged to seepage basins.

The decontaminated salt equivalent to about 29 million gallons of saltcake would be stored in 27 existing Type-III waste storage tanks (1 million gallons per tank) and four Type-I tanks (0.55 million gallons per tank). The waste tanks consist of carbon-steel primary vessels that are contained within carbon-steel secondary vessels, or pan for Type-I tanks. A concrete vault (walls 2.5 to 4 feet thick) encloses both type tanks and provides additional containment. All tanks used would be located above the water table. No new tanks would be required.

During decommissioning of the waste tanks, roof penetrations would be sealed, and empty spaces including unused tank volume and the annulus between primary and secondary vessels, would be filled with concrete. Additional isolation from the environment would be obtained by covering the tank roof with a clay cap and a layer of soil.

The principal advantage of terminal storage of decontaminated salt in empty waste tanks as dewatered saltcake is potentially lower capital and operating costs compared to other salt-disposal alternatives. However, the potential for contamination of surroundings by release of high-solubility salt and its associated radioactivity are greater than for the other alternatives considered. An additional disadvantage is that tank storage may not be perceived as the final disposition of the waste.

Costs

Costs for storage of saltcake in SRP waste tanks were estimated to total $4 million capital charges and $2 million/yr operating expenses. Cost breakdowns are as follows:

Capital	10^6 $	Operating	10^6 $/yr
Evaporators	4	Evap. Transfers	2
Total	4	Total	2

Environmental Effects

Environmental impacts of storage of decontaminated saltcake in SRP waste tanks were assumed to result from loss of tank integrity and infiltration of rainwater allowing leakage of salt solution. Following decommissioning and abandonment, the waste tank vessels and structures including seals would deteriorate gradually because of corrosion and weathering effects. Effective tank life before water infiltration was assumed to be about 200 years; the rate of leakage after this time would be controlled by the hydraulic conductivity of tank top and protective clay cap. Once out of the tank, saltcake constituents such as nitrate/nitrite, Tc-99, and I-129 that have no potential for retardation in soil would move with the groundwater; other constituents would migrate at rates controlled by soil retardation factors. Discharge from ground outcrops to tributary streams would be conveyed to the Savannah River.

The lack of structural stability of saltcake in the presence of infiltrating rain water would be expected to have major environmental consequences. Leakage of dissolved salt from a tank filled with saltcake would remove material support for the tank top and protective covers, allowing collapse of the structure at some time. Failure of the protective cover would allow large quantities of infiltrating rainwater to reach the residual saltcake and produce potentially massive contamination of surface and subsurface surroundings.

DISCUSSION

Comparison of Projected Costs

Total costs for disposal of the SRP decontaminated high-level waste salt, including initial capital costs and 31-year accumulated operating costs, are summarized in Table V. The total costs, discounted to present value by standard procedures, range generally from $19 million in 1982 dollars for storage as saltcake in existing SRP waste tanks to $103 million for trench burial as saltcrete monoliths in the unmodified reference process. Initial capital costs for the same disposal options range from $4 million to $36 million. Development of the permeation-resistant soil/saltcrete form to eliminate the need for clay-lined trenches reduces total costs of the reference process by $15-$42

million, depending on whether or not Tc-99 is removed. With this modification, the cost of the reference process ($61-$88 million) is about the same as that of land application ($72 million), with Tc-99 removal and additional polishing to reduce Sr-90 and Cs-137 concentrations, and as unpackaged ocean disposal with pipeline transport of the salt solution ($79 million). The only alternative besides saltcake disposal in waste tanks with a significantly lower cost is unpackaged ocean disposal with truck transfer to Savannah River barges ($27 million), which would benefit from both low capital and operating costs. Ocean disposal as packaged waste is a comparatively high cost option ($99 million), because of relatively high operating costs associated with the packaging process.

Table V. Summary of Costs for Decontaminated Salt Disposal Processes

Process	Capital Cost 10^6 $	Operating Cost 10^6 $/yr	Total Cost[a] 10^6 $	Discounted Total Cost[b] 10^6 $
Reference - Saltcrete	23	7	240	76
Ref. with Tc removal	36	9	315	103
Ref. - Soil/Saltcrete	24	5	179	61
Land Application (with additional decontamination)	36	5	191	72
Ocean Disposal - Contained	23	10	333	99
Ocean Disposal - Uncontained				
Truck Transfer	4	3	97	27
Pipe Transfer	62	3	155	79
Saltcake-Waste Tanks	4	2	66	19

[a] Total cost is capital plus operating cost for 31 years (1986-2016) in constant 1982 dollars.

[b] Discount Rate - 10%.

Comparison of Environmental Effects

Review of environmental impacts discloses no overriding obstacles to disposal of the decontaminated SRP salt for the several disposal options considered, except for the terminal storage as saltcake in waste tanks, for which massive contamination of surrounding areas could result from collapse of protective covers. However, regulatory obstacles could well eliminate both land application and ocean disposal.

The reference saltcrete burial process potentially meets all NRC requirements for low-level waste burial — in particular, limits on occupational radiation exposures, limits on radionuclide concentrations assuring intruder protection, and limits on releases of radioactivity to the public. For saltcrete burial, control of chemical releases are more critical than control of radionuclide releases, and landfill as well as waste form characteristics must be tailored to meet applicable standards.

For the land application process, in contrast, releases of chemical constituents are of relatively minor concern. The major constituent of the waste, nitrate-nitrite salt, serves a beneficial use as fertilizer for non-food crops. Control of residual radioactivity in the salt is much more critical, however, and polishing to reduce residual concentrations of Cs-137, Sr-90, and Tc-99 to very low levels would be necessary to prevent exposures to offsite consumers of drinking water and foodchain products from exceeding specified limits. Land application has the advantage of making the salt useful as a source of nitrogen, but the perceived environmental problems could make it difficult to obtain timely approval.

Ocean disposal of decontaminated salt has not been studied in depth. Packaged as low-level radioactive waste, the salt would appear to qualify for ocean disposal under existing international regulations. As unpackaged waste, salt disposal in the ocean would require detailed food chain analyses to determine its effects; institutional acceptance might not be readily obtainable.

Development of saltcrete burial in onsite trenches as the reference process for SRP salt disposal is continuing. This process is the only option studied that can be demonstrated at this time to meet all environmental and regulatory requirements.

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