COST/BENEFIT SYSTEMS ANALYSIS AND COMPARISON OF SHALLOW LAND BURIAL AND GREATER CONFINEMENT DISPOSAL

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ABSTRACT

The management of low-level radioactive waste (LLW) has, over the past few years, become an increasingly sophisticated and expensive problem for LLW generators, particularly utilities. The main area in the LLW management system, which includes volume reduction, solidification, packaging, handling, transportation, and disposal, that has really seen a dramatic increase in costs over the last few years is the disposal of LLW. In response, utilities are increasingly looking into various volume reduction alternatives to reduce these disposal costs. The time is ripe and the need evident for an analysis that considers the entire LLW management system, not just selected parts. To help meet this need, a cost/benefit and sensitivity analysis was performed of the entire LLW management system to see if greater confinement disposal is a potential cost effective alternative to shallow land burial. The results of this analysis are presented in this paper which concludes that greater confinement disposal can be a cost effective alternative to shall land burial for a few LLW management configurations.

INTRODUCTION

In the past, commercially generated LLW has been disposed of in shallow land burial (SLB) disposal facilities. However, high-specific-activity wastes and wastes containing long-lived isotopes are not suitable for SLB because of their radioactivity and longevity, respectively. In addition, these wastes pose a potential hazard to man if buried in an SLB facility. For these reasons, a safe, economical alternative to current techniques for disposing of these wastes is needed. Burying these wastes in facilities utilizing the greater confinement disposal (GCD) concept may be such an alternative.

The benefits that GCD have over shallow land burial are (1):

1. greater isolation and protection of the waste from natural and man-induced events,
2. greater protection against sabotage and accidental intrusion,
3. greater confinement of the radioactivity contained in the waste containers,
4. more possible uses of the site after institutional controls have ended, and
5. less long term care and maintenance.

The objective of this research study will be to determine if greater confinement disposal is a cost effective alternative to shallow land burial. This will be done by performing a cost/benefit systems analysis and sensitivity analysis on cost parameters associated with the LLW management system.

LLW SYSTEM COSTS

An attempt was made in this analysis to utilize costs based on actual operating experiences as much as possible. To accomplish this objective, nuclear power plants were surveyed to obtain actual costs associated with volume reduction equipment, solidification equipment, handling equipment, containers, transportation, and disposal. In addition, vendors of LLW treatment systems and services were surveyed to obtain their estimated costs to acquire and use their systems. Where actual costs were not available, such as for the various greater confinement disposal techniques, estimated costs from the literature were used.

The initial scope of this analysis was to also acquire these same costs from institutional facilities, such as hospitals, and national laboratories but limited time and resources prevented this extension.

Volume Reduction Costs

One apparent result of the surveys of vendors of volume reduction equipment was that costs were highly variable. This variability was mainly due to large dependence on economics-of-scale or, in other words, LLW throughput capacity. This was particularly true of construction and installation costs which depended on whether space already existed for the equipment or whether a new building needed to be constructed to hold the equipment. To take this variability into account, high, low, and median ranges were placed on the costs for use in the sensitivity analysis. Table I summarizes those cost ranges for the different types of volume reduction systems.

In addition to the cost variability, a significant variability in the volume reduction factors achieved by these systems was also reported. This variability was found to not only result from different types of waste stream inputs but also from different material compositions within the same waste streams. Again, to take this into account, high, low, and median volume reduction factors were used. These volume reduction factors are presented in Table II for each major LLW stream produced by nuclear power plants.

Solidification Costs

Costs for solidification systems were obtained mostly from nuclear power plants. As with volume reduction costs, these costs were quite variable necessitating the need to place a range on these costs also. Table III summarizes these costs for two different types of binders.

Volume increase factors for these solidification systems were quite variable for the same reasons mentioned above. A summary of these factors is given in Table IV for each type of LLW stream.

TABLE I

Volume Reduction costs (in millions)

Technology	Cost Range	Acquisition Cost ($)	Building and Installation Cost ($)	Operating Cost ($/yr)	Lifetime (yr)
Mobile Incineration	low	1.8	0.5	0.15	20
	mean	2.4	0.75	0.175	20
	high	3.0	1.0	0.2	20
Incineration	low	2.5	5.0	0.03	40
	mean	3.5	10.0	0.13	40
	high	4.5	15.0	0.23	40
Incineration and Drying	low	2.5	5.0	0.05	30
	mean	3.75	10.0	0.15	30
	high	5.0	15.0	0.25	30
Spray Drying	low	0.6	1.0	0.15	15
	mean	1.05	1.25	0.033	15
	high	1.5	1.5	0.05	15
Mobile Spray Drying	low	0.4	0.1	0.1	15
	mean	0.6	0.3	0.125	15
	high	0.8	0.5	0.15	15
Evaporation and Solidification	low	2.0	3.0	0.25	40
	mean	3.5	5.0	0.3	40
	high	5.0	7.0	0.35	40
Dewatering (Centrifuge)	low	0.0	0.0	0.043	40
	mean	0.335	0.1	0.010	40
	high	0.5	0.3	0.015	40
Shredding	low	0.2	0.01	0.05	20
	mean	0.25	0.03	0.075	20
	high	0.3	0.05	0.1	20
Shredding and Compaction	low	0.3	0.01	0.05	30
	mean	0.375	0.03	0.075	30
	high	0.45	0.05	0.1	30
Compaction	low	0.04	0.005	0.0025	30
	mean	0.06	0.0075	0.0045	30
	high	0.08	0.01	0.0065	30

Packaging Costs

Several different types of containers are currently being used to package LLW. These different types include:

1. metal boxes,
2. steel drums,
3. steel liners,
4. HIC drums, and
5. HIC containers.

These different types of containers arise as a result of 10 CFR Part 61 requirements for waste stabilization. Since dry active waste (DAW) is not required to be stabilized it is usually placed into metal boxes or steel drums. Liquid wastes and Class B and C wastes, which require stabilization, can be (2):

1. solidified into a steel drum or steel liner, or
2. dewatered and placed into HIC drums or HIC containers, or
3. placed into a specially designed disposal facility.

The containers used in this study and their associated costs are presented in Table V.

Transportation Costs

The cost of transporting LLW from a nuclear power plant to a disposal facility is usually segregated into two types: unshielded and shielded shipments. The results of a survey of nuclear power plants yielded Fig. 1, the cost of shipping unshielded LLW, and Fig. 2, the cost of shipping shielded LLW. As with the volume reduction and solidification equipment, upper and lower bounds were placed on these costs.

Handling Costs

No firm methodology for determining costs connected with the handling of LLW could be established.

Disposal Costs

Costs to dispose of LLW via both shallow land burial and greater confinement disposal were obtained from the literature. Even though actual costs are available for SLB it was felt that costs derived from the same types of economic analyses should be used to

TABLE II

Volume Reduction Ratios

Technology	Range	Compactible Trash	Ion Exchange Resins	Concentrated Liquids	Filter Sludge	Cartridge Filters
Mobile Incineration	low	35.0	--	--	--	--
	mean	67.0	--	--	--	--
	high	100.0	--	--	--	--
Incineration	low	10.0	0.0	--	0.0	0.0
	mean	55.0	25.0	--	25.0	25.0
	high	100.0	50.0	--	50.0	50.0
Incineration and Drying	low	30.0	6.0	5.0	5.0	20.0
	mean	55.0	10.0	20.0	10.0	35.0
	high	100.0	50.0	50.0	50.0	50.0
Spray Drying	low	--	3.0	3.0	2.0	--
	mean	--	3.5	4.5	2.75	--
	high	--	6.0	6.0	3.5	--
Mobile Spray Drying	low	--	5.0	5.0	5.0	--
	mean	--	7.5	7.5	7.5	--
	high	--	10.0	10.0	10.0	--
Evaporation and Solidification	low	--	1.25	1.5	2.25	--
	mean	--	1.5	1.625	3.5	--
	high	--	1.75	1.75	4.75	--
Dewatering (Centrifuge)	low	--	1.1	--	1.1	--
	mean	--	1.25	--	1.25	--
	high	--	1.5	--	1.5	--
Shredding	low	1.2	--	--	--	--
	mean	1.33	--	--	--	--
	high	1.5	--	--	--	--
Shredding and Compaction	low	8.0	--	--	--	--
	mean	9.0	--	--	--	--
	high	10.0	--	--	--	--
Compaction	low	4.0	--	--	--	--
	mean	6.0	--	--	--	--
	high	8.0	--	--	--	--

TABLE III

Solidification Costs (in millions)

Binder Type	Cost Range	Acquisition Cost ($)	Building and Installation Cost ($)	Operating Cost ($/yr)	Lifetime (yr)	Volume Processed (ft^3/yr)
Cement	low	1.0	0.1	0.12	40	5,000
	mean	1.6	0.3	0.26	40	10,000
	high	2.2	0.5	0.4	40	20,000
Dow Polymer	low	1.0	0.1	0.28	40	5,000
	mean	1.6	0.3	0.585	40	10,000
	high	2.2	0.5	1.05	40	20,000

TABLE IV

Volume Increase Ratios

Binder Type	Range	Ion Exchange Resins	Concentrated Liquids	Filter Sludge	Cartridge Filters	Ash
Cement	low	1.33	1.33	1.33	1.33	1.5
	mean	1.6	1.4	1.4	1.4	2.0
	high	2.0	1.5	1.5	1.5	2.5
Dow Polymer	low	1.75	1.33	1.33	1.75	1.33
	mean	2.0	1.5	1.5	2.0	1.5
	high	2.25	1.67	1.67	2.25	1.67

TABLE V

Waste Container Costs (3)

Container	Burial Volume (ft^3)	Waste Volume (ft^3)	Unit Cost ($)
Metal Box	106	96	600
Steel Drum	8.6	7.5	25
Steel Liner	195	170	4,000
	138	120	3,000
	57	50	1,200
	23	20	500
HIC Drum	8.6	7.5	250
HIC Container (4)	150	70	8,000

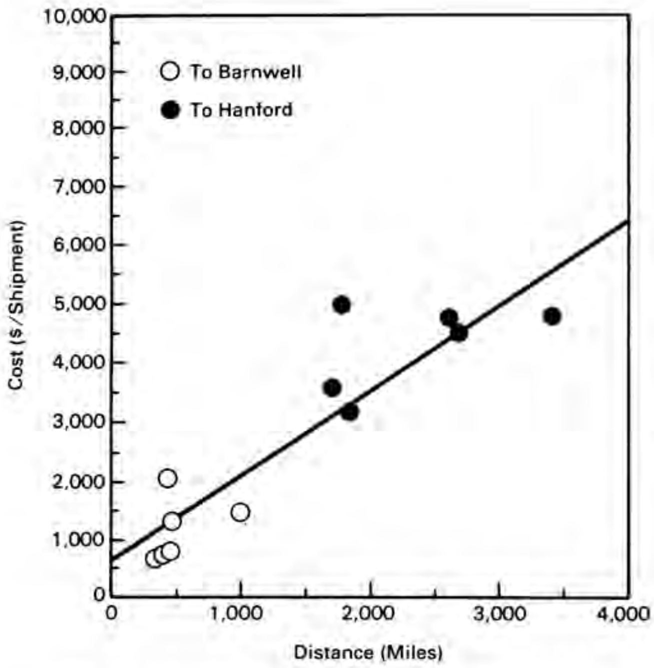

Fig. 1. Cost of Transporting Unshielded LLW

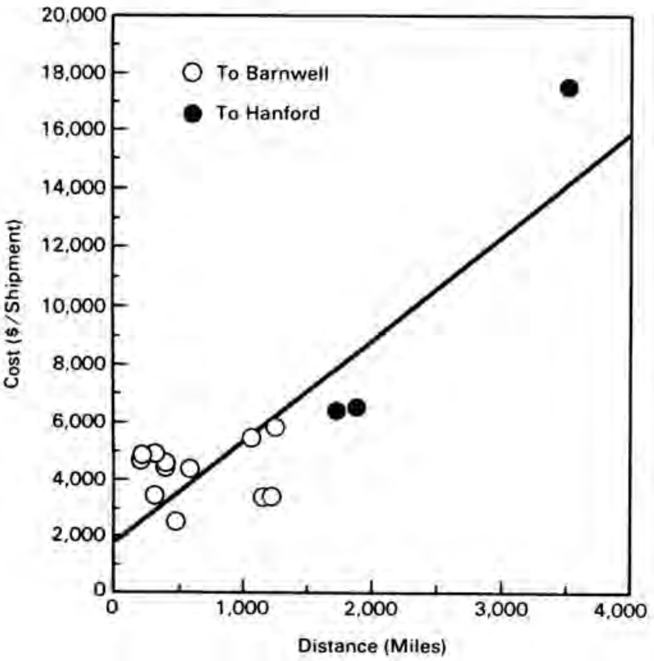

Fig. 2. Cost of Transporting Shielded LLW

maintain consistency since no commercial size GCD facilities exist. A summary of the costs of SLB and various GCD alternatives is presented in Table VI.

Health Risk Costs

Since the greatest benefit that greater confinement disposal has over shallow land burial is the additional protection against radiation exposure to both on-site workers and the general population, it was felt that some how this needed to be taken into account in the comparative analysis. Assigning costs to the health risks associated with each type of disposal alternative in Table VI was the chosen method to account for this benefit.

The total health risk for each disposal alternative was obtained by summing the individual health risks, radiation exposure, over the expected number of intruders and the population within 80 kilometers of the waste disposal site. This risk was then converted to cost by assigning a value of $1,800/person-rem of exposure (5).

This analysis yielded a health risk cost, for Class C waste, of approximately $\$17/ft^3$ of waste disposed via shallow land burial. The corresponding value for the deep trench and intruder barrier techniques was approximately $\$3/ft^3$ while for the concrete-walled trench and the augered shaft the cost was negligible. The health risk cost associated with Class A and B waste was found to be negligible for all disposal alternatives.

COST/BENEFIT AND SENSITIVITY ANALYSIS

A cost/benefit analysis is used to compare different strategies for managing the different classes of low-level radioactive wastes. The analysis assumes that the only cost incurred is the cost (VR) of acquiring and operating additional volume reduction equipment. Savings in solidification (SC), packaging (PC), transportation (TC), disposal (BC), and health risk (HR) costs resulting from the volume reduction system are assumed to be benefits. The benefit/cost ratio was, therefore, calculated as follows:

$$\frac{B}{C} = \frac{\Delta(SC) + \Delta(PC) + \Delta(TC) + \Delta(BC) + \Delta(HR)}{\Delta(VR)} \quad (1)$$

where Δ represents the cost difference between the two alternatives being analyzed.

A computer simulation model was developed to perform the cost/benefit analysis and to permit sensitivity analyses of the various input parameters.

RESULTS AND CONCLUSIONS

The cost/benefit and sensitivity analysis was performed separately for each of the following low-level waste streams: ion exchange resins, filter sludge, concentrated liquids, cartridge filters, and compactible trash. In addition, the waste streams were segregated as to origin, pressurized water reactor (PWR) or boiling water reactor (BWR), and analyzed separately. Finally, all waste streams were analyzed as one to determine the best waste management system for both PWRs and BWRs.

The results of these analyses indicate that the most cost effect method of managing wet wastes from both single and twin unit PWR power plants is to solidify them and ship them to an SLB facility. Triple unit facilities, on the other hand, will find the use of a spray dryer used in conjunction with a GCD facility to be the preferred management method. The analysis also indicates that cartridge filters should

TABLE VI

Comparison of Costs for Various LLW Disposal Alternatives ($/ft^3)

Source of Information (Reference)	Shallow Land Burial	Deep Trench (16-meter Cover)	Intruder Barrier	Concrete-Walled Trench	Augered Shaft (Above) Water Table)
ANL 5[a]	38.52	55.51	58.34	78.16	64.00
REECO 6[b]	7.73	8.28	8.68	--	9.24
Wacks 7[c]	--	--	2.79	2.38	13.52

(a) Based on a 17,500 ft^3/yr facility colocated with a shallow land burial facility. Costs include $400,000 per year for four years of closure and $40,000 per year for 100 years of institutional control.
(b) Based on a 1,765,000 ft^3/yr facility.
(c) Based on a 2,860,000 ft^3/yr facility.

be packaged and shipped for GCD disposal while compactible trash should be packaged and sent to an SLB facility.

Spray drying of wet wastes and shipping the final waste form to a GCD facility was found to be the most cost affective alternative for BWR power plants. As with PWRs, cartridge filters should be packaged and sent for GCD disposal while compactible trash should be packaged and sent for SLB disposal. On the other hand, if the BWR is a triple unit station then the compactible trash should be shredded before packaging and disposal.

A final word of note is that incineration used with GCD becomes an increasingly better alternative as larger volumes of waste are incinerated. For a three unit BWR it is just about as cost effective as the spray drying alternative for wet wastes. The conclusion from this result is that an incineration facility centrally located near several power plants would be a cost effective method for managing low-level wastes.

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