LONG-RANGE LOW-LEVEL WASTE MANAGEMENT NEEDS

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INTRODUCTION

The term "long-range" is relative. It could denote several budget cycles, the better part of some life time or even an incremental unit of geological time. Those of us who have worked in the field of environmental engineering have grown accustomed to resolving pollution abatement problems in terms of all the above definitions. Yet, there are those around us who do not comprehend the fact that the use of the word long-range does not mandate an overkill reaction or an arbitrary use of the zero-risk concept. The objective of any abatement challenge is to accomplish the task within a real-world setting, to resolve the problem within established limits, to provide flexibility for implementation of remedial alternatives, to accomplish the task of waste disposal within economic reality, and to expect risks commensurate with those surrounding mankind's normal environment. In all waste management considerations, it is necessary to establish the waste source; characterize the waste components; determine treatability; evaluate specific details that comprise a systems approach to overall waste management; and implement practical collection, packaging, storage disposal and monitoring technology.

LLW are those wastes that are not high-level or transuranium-contaminated wastes. Also, LLW with more than 10 n Ci/g of Pu is termed TRU waste. At this threshold the dose to humans is roughly equivalent to that from radium in naturally occurring ores in the Colorado Plateau.

The problems associated with the management of LLW and domestic garbage are not altogether different. Historically, the disposal of garbage has created intense political and social debates. The two major differences between LLW and non-radioactive solid waste are the viewpoint of the public about anything associated with nuclear power and the Federal government's involvement with LLW.

Both of these attributes have sparked local political sideshows. There is no reason to believe that this political verbage will cease. At least not until national and state leaders emerge who are capable of recognizing the problem for what it is and will proceed to implement logical waste disposal plans. As has been suggested by past managers of waste disposal systems, the economics of all political systems are oiled with money: the value of disposal facilities are judged in terms of monetary cost; the acceptability to the environment is somewhere between zero and some judgmental dilution factor.

The objective of this paper is to evaluate management considerations by defining the source and magnitude of LLW, relating base-level exposure relationships, developing a framework for LLW disposal, defining principles for LLW burial, and listing LLW burial considerations.

SOURCE AND MAGNITUDE OF PROBLEM

The sources of LLW are users of radioactive isotopes, producers of commercial electric power, and the Department of Energy (DOE). The extent of LLW production and alternative disposal methodologies associated with shallow land burial of low-level radioactively contaminated solid waste have been exhaustively analyzed by a Committee of the National Academy of Sciences.[1]

U.S. industries and institutions are producing increasing amounts of LLW. As more nuclear reactors begin operating, the yearly production of low-level waste will accelerate significantly. Unfortunately, many industries and institutions may soon have no safe or economical disposal facility available.

Every state produces LLW. Until recently South Carolina reportedly has been receiving 85% of all LLW or about 240,000 cu. ft.* per month. To relieve the political pressures of being tagged this country's garbage dump, South Carolina has given the other states an opportunity to solve their own problems by cutting back their acceptance to 100,000 cu. ft. per month within a two-year period.[2] The state fee for accepting LLW has increased from 16 cents to 55 cents per cu. ft. and will be further increased to $1.00 per cu. ft. by April 1981.

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* 1 cu.m. = 28.32 cu. ft.)

There are about 1,100 physicians and scientists actively practicing nuclear medicine. During 1979 about 10 million nuclear medicine imaging and functioning studies were performed and about 60 million nuclear medicine assay procedures were conducted.[3] Some research institutions have already placed a moratorium on the use of carbon-14 and tritium research. A Michigan study estimates that the average cost per day per patient would increase by $3.00 if they stopped using radioactive isotopes.[4]

The total problem is exemplified by the Texas situation. In 1978, virtually all of the LLW generated in Texas was disposed of at the Chem Nuclear waste facility near Barnwell, South Carolina, the only disposal facility east of the Rocky Mountains. Ten state-supported institutions spent $115,000 to dispose of LLW. Transportation costs account for 60% of total disposal. Shifting to burial in Beatty, Nevada or Richland, Washington, respectively, would increase the cost 50% or 100%.

The total costs are expected to rise drastically because: (a) fuel costs will increase; (b) state and local taxes associated with licensed disposal facilities will surely increase; (c) licensed disposal operators will probably charge whatever the market place will bear; and (d) more LLW will be generated.

Of the five billion metric tons (MT) of solid waste generated in the U.S. during 1977, 344 MT of industrial waste were disposed of _in situ_; 132 MT of municipal waste utilized about 2.02×10^9 m^2 of land; and only 0.04 tons (excluding mill tailings) contained what would be classified as radioactive LLW, Table I. Since 1940 about 1.2 million MT of radioactive waste have been generated, excluding mill tailings. In terms of volume, 3 million cu. ft. of LLW are generated annually.[5] Of this amount about 30% is derived from medical usage of radioisotopes, 50% from nuclear-reactor and fuel-cycle wastes, and 20% from a variety of industrial and governmental sources.

The waste generation from a normalized 1000 MWe LWR indicates a range of LLW from 5,000 to 45,000 cu. ft./yr. on-site and 2,000 cu. ft./yr. off-site (not including mill tailings), Table II. As of 1977, about 16 and 51 million cu. ft., respectively, of commercial and DOE LLW were buried.

The quality of tailings generated from uranium-bearing ores containing 0.5% to 0.25% uranium by weight is roughly equal to a mill tailings volume of 127 million MT. Approximately 40,000

MT of tailings are generated annually. Although this amount of LLW appears to be large, let us make a comparison with the disposable waste derived from a coal-fired electric plant. For a coal-fired electric plant using 100 carloads of coal per day, 10 carloads of ash will be produced. All of the ash will contain varying amounts of radioactivity. For a 1000 MWe coal-fired unit, using western coal, the annual ash and sludge accumulation would constitute an equivalent waste dump that covered an area of 40 acres (16 ha) and a depth of 7 ft. (2.1 m.).

Base-Level Relationships

Apparently no one can say with certainty that there is "no risk" in generating or disposing of low-level radioactive wastes. However, deleterious effects on the populace are believed to be unmeasurable and the benefits are justifiable and measurable.

According to the Environmental Protection Agency, roughly 50% of the radiation to which the U.S. population is exposed is

Table I. Estimated Quantitites of Solid Waste Generated in the United States in 1977[6] (wet weight)

Waste Source	Metric Tons	Average (%)
Municipal	132	2.5
Sewage Sludge[a]	4.5	0.1
Junked automobiles and construction demolition[a]	41	0.7
Industrial		
Nonhazardous	292-310	5.6
Hazardous	34-52	0.8
Radioactive[a-b]	0.04	0.1
Mining and Milling[c]	2086	39.0
Agricultural	2265-3014	50.4
Utility[d]	70	1.3
	4925-5710	100.0

[a] Dry weight.

[b] Accumulated total divided by number of years of waste generation; estimate based on density of 560 kg per m^3, excluding mill tailings.

[c] Tailings in dry weight; includes uranium mill tailings.

[d] Excludes radioactive waste.

Table II. Annual Waste Generation Rates[7]
(Normalized to a Typical 1000 MWe LWR)

Spent Fuel Discharged (Ave.)	25.4 MT HM/yr (332 ft^3/yr)
Low Level Waste, On-site [a]	
a) Present Experience	45,000 ft^3/yr
b) Design Basis	15,000 ft^3/yr
c) Advanced Volume Reduction [b]	5,000 ft^3/yr
Low Level Waste, Off-site	
a) Uranium Mill, Tailings Solutions [c]	254,000 MT/yr
Tailings Solids [d]	96,000 MT/yr
b) UF_6 Conversion	1,200 ft^3/yr
c) Enrichment	50 ft^3/yr
d) Fuel Fabrication	750 ft^3/yr
Transuranic Waste, On-site and Off-site	0

[a] Roughly 40% of current volumes generated is contaminated trash.

[b] This estimate reflects the use of methods which are presently not economical. Current, allowable activity levels per package may preclude actual achievement of this level in the future.

[c] These wastes are currently disposed of at the processing facility site.

[d] This value is based on gaseous diffusion technology. The new centrifuge process could potentially generate more (up to 2900 ft^3/yr.)

derived from natural sources.[8] About one-third of this background ionizing radiation is the form of cosmic rays. The residual is derived from sources such as mineral deposits. This total dose is very low, amounting to about 0.1 to 0.2 rem per year. Medical procedures account for about 40% of the total exposure of the general population. Radioactive fallout from nuclear weapons tests represents about 3% of the exposure. Technologically enhanced natural radiation, i.e., mining and processing uranium, is alleged to contribute about 2.5% of the total exposure. Finally, other sources of radiation exposure are derived from the use of nuclear energy to produce electricity, consumer products containing radium and radionuclides and television.

Average population explosures[9] in the U. S. are as follows:

Natural Background	102	m rem/yr
Global Fallout	4	m rem/yr
Nuclear Power	0.003	m rem/yr
Diagnostic Medical	72	m rem/yr

Radiopharmaceuticals	1	m rem/yr
Occupational	0.8	m rem/yr
Miscellaneous	2	m rem/yr
	182	

Basically, exposure levels below 1 rem, and particularly 0.1 rem produce dose-effect data that are difficult to correlate. Certainly the effect of exposures of 0.1 rem or less are probably undetectable. Table III clearly depicts the lack of positive correlations between cancer mortality and chronic low-level radiation.

For further comparison, exposure to external radiation in the West, specifically Denver-Boulder area is about double that in New York and the area around Three Mile Island at the time of the accident. Apparently there is no evidence of increased cancer rates, abnormal births, or other deleterious effects as a result of increased ionizing radiation in Denver.[10]

Similarly, the human body contains natural radioactivity. The predominant radioisotopes are 0.1 Ci K^{40} and 0.1 Ci C^{14}. If the same Nuclear Regulatory Commission rules applied to man as to a laboratory animal that received this amount of radioactivity, a human being, upon death, would have to be packed into a small can, inside a larger can, and transported to a licensed disposal site.

FRAMEWORK FOR LLW DISPOSAL

The framework used to implement LLW disposal can significantly affect the deployment of waste disposal technologies and strategies. Consequently, long-range management requires the integration of possibly six major considerations using a systems approach. These are:

1. Legal and Institutional Analysis--legal issues and role of federal, state, and local government and non-governmental group involvement in the LLW management and decision-making process.

2. Alternative Frameworks for Regulatory LLW Disposal--hazards associated with LLW, alternatives and implications of different regulatory frameworks, technologies and strategies, concepts and criteria of safety, numerical standards, philosophies for "proving" that criteria and/or standards will be met.

3. Non-Radiological Impacts Associated with Radioactive Waste Disposal--social, environmental, economic and political impacts and assessment of methodologies for identifying, measuring, interpreting and communicating impacts as required by NEPA and CEQ.

4. Evaluation of International Issues Related to LLW Disposal--potential international actions that might significantly affect the deployment of long-term waste management strategies in U.S.

5. Historical Waste Management Policies in U.S.--impact of private and public actions, assessment of apparent implications of government policy changes, etc.

6. Public Participation

It is important to note that the management and utilization of nuclear energy by-products must be put in a bioethical prospective alonside of other energy production cycles.[12] Unfortunately, the more studied risks are not necessarily the most important.

PRINCIPLES FOR LLW BURIAL

There are a few principles that can be highlighted when considering shallow burial of LLW.[13] First, possible pathways for radioactive migration are: site occupational losses, including ground water transport to watercourses and spillage resulting in contamination to both water and air; personal intrusion resulting in inhalation and uptake by agricultural crops; and natural water and air erosion.

Second, biological pathways play a minor role in actual material transport with essentially no effect on the contaminant inventory, but biological transport plays a major role in determining exposure of organisms to radionuclides.[14]

Third, hydraulic transport is considered to be the primary problem. For hydraulic transport to take place there must be a breach of the waste containment system that results in the formation of leachate.

Fourth, the leachate for many LLW burial sites could have characteristics of typical sanitary land fills that have been breached with water.[14] Water movement depends on pressure gradients in the water table. The transport of radionuclides in porous

Tabel III. Effects of Chronic Low-Level Radiation[11]

Item	Unit	Location				r with cancer
		A	B	US	C	
Natural Background	mrem/yr	210	170	130	118	-0.959
White Population	1000's	5735	16897	158051	59683	
All Malignancies	per 10^5	126.3	132.2	149.5	146.8	1.000
Altitude	ft	4510	2650	900	730	
Urbanization	%	63	57	69	74	+0.777
Years of School		11.8	11.7	10.9	10.8	
Suspended Particulate in Air	ug/m^3	129	119	115	116	-0.889
Benzene Soluble SPM	ug/m^3	10.1	9.3	9.5	9.6	-0.465
Urban Air Radioactivity	pCi/m^3	8.5	7.7	6.8	6.3	-0.944
Beta Activity in Air	pCi/m^3	5.5	5.2	4.4	4.2	-0.974
Mortality Rate (All Causes)	per 10^5	892.0	893.2	928.5	903.9	
Lung Cancer Mortality	per 10^5	14.5	15.5	20.4	21.5	

media will be dependent on these driving forces plus additional mechanisms such as convection, diffusion and dispersion, sorption, radioactive decay, and chemical properties of waste. Improvements have been made for modeling geosphere transport. Mathematical models and corresponding analytical solutions are available to evaluate the sensitivity of potential releases into the environment to the characteristics of waste isolation systems.[16-17] Analytical solutions could probably be extended to include: multiple dimensions, multiple media with different water velocities, dispersion coefficients, and/or retardation factors; certain nonconstant uptake or release rate situtations; element-specific leach rates; rate-controlled sorption; multiple and chemically reacting species of specific nuclides; irreversible sorption reactions; and reversible precipation.

Fifth, volume reduction ultimately must become an important consideration in LLW management. For volume reduction there are no real alternatives to compaction and incineration. The advantages are: a) ease in handling and transporting, b) elimination of spontaneous fire hazards, c) minimizing packaging problems, and d) under some conditions, retrievability of the waste can be implemented. It has been estimated that 50% of the solid waste generated by DOE is suitable for volume reduction by compaction.[1] Incineration may achieve 80% to 90% volume reduction, excluding residues from offgas treatment and refractory wastes. In contrast incineration of some municipal waste may reduce the volume only 20% to 30%, but this is important because about 80% of the cost is spent on collection.

Sixth, optimization of interfacing volume reduction and solidification methods is the ultimate key to reductions in cost. Advanced unit processes can be explored that can decrease personal exposures, reduce volume of waste, and yield products more compatible with solidification processes. Advanced LLW treatment might include microwave heating, freeze drying and autoclave oxidation. Solidification agents may enhance LLW disposal in some areas. Alternatively, the cost of volume reduction and disposal in suitable deep geologic formations will cost about $60 per cu. ft. as compared with 1979 burial ground procedures. Assuming placement of 275, 000 cu. ft. of LLW can be buried per acre in deeper geological formations, this volume reduction alternative places a value of up to $10 million on each acre saved.[7]

LLW BURIAL CONSIDERATIONS

Specific LLW burial considerations must involve overall collection, transport, retrievability, site-specific characteristics, and sound managment. There is an economic relationship between waste disposal costs, on-site waste management and waste production.

Desirable features, but not necessarily requirements, for LLW disposal sites, are: a) absence of a water drive; b) slow surface erosion rate; c) desert climate; d) absence of non-renewable resource; e) accessibility, f) available construction materials; and g) absence of special environmental attractions.

Virtually all hazards associated with a well-planned and designed waste disposal facility are associated with people. Problems of managment are usually administrative or disciplinary. Training, motivation, discipline, and alert management are of particular importance in managing a "garbage" disposal facility.

SUMMARY AND CONCLUSIONS

Most LLW storage/disposal practices are continually improving. The hazard associated with a well-managed LLW facility to anyone now or in the long term is negligible. With respect to present LLW burial sites, the greatest risk is associated with re-entombment.

Current technology provides a safe method of disposal of LLW. However, LLW disposal facilities located in each state or region offers users of radionuclides several advantages. It may be desirable to categorize LLW into potentioal biological subcategories and characteristics. To further enhance confidence in long-term containment, a more detailed systems approach to containment and isolation should be utilized. A multibarrier system incorporating engineered barriers, selected geologic media and minimal transport possibilities continues to be the basis for logical design.

The concept of transporting LLW across the U.S. represents a misuse of public funds, and possibly results in increased national radiation exposure levels.

States will have a more difficult time resisting the location of federal nuclear waste disposal sites within their borders if they have made no effort to develop their own resources. Federal policies have been known to be largely reactive and unimaginative. It is probably time for Congress to mandate responsibility of LLW disposal to the states for that waste which has been generated within a state. Also, Congress should establish a mechanism - whereby states can enter into interstate compacts for management, processing, storage, and disposal of LLW. Concurrently, it is necessary for the state legislators to recognize the public need for local LLW disposal and to designate a lead agency to license and regulate LLW facilities in accordance with state and federal laws. States must ensure adequate user funding to cover costs of operating, decommissioning, and monitoring the LLW facilities.

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