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# ALTERNATIVES TO SHALLOW LAND BURIAL

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## ABSTRACT

During FY79 and FY80 the Los Alamos National Laboratory and its contractors performed a preliminary assessement of several alternatives to shallow land burial of low-level waste, including deeper burial, mined cavities, specially engineered storage buildings, well injection of liquid waste, and seabed disposal. Only deeper burial and mined cavities seem acceptable as near-term alternatives. A waste management program using a combination of disposal alternatives is recommended. Research needed to implement the deeper burial and mined cavity options is identified.

## INTRODUCTION

Since the early 1940s, solid low-level radioactive wastes (LLW) have been disposed to shallow trenches and shafts. With the exception of limited use of absorption beds and injection wells liquid wastes have been solidified and buried. Until the early 1970s, some wastes were dumped into the ocean. Shallow land burial (SLB), however, has historically been the primary means of radioactive waste disposal in the United States.

Initially, SLB was intended to provide better containment than conventional landfill practices of the time. The advent of commercial nuclear power production and the increasing use of radioactivity for medical and industrial purposes have resulted in ever-increasing volumes and varieties of waste types and waste forms. Many high-activity and/or mobile wastes are not suited to SLB. Repeated releases from disposal trenches resulting in the closing of commercial burial facilities strongly suggest that SLB, as currently practiced, is not adequate as a disposal method for LLW.

Several options exist as means to alleviate this situation and to reduce the likelihood and consequences of exposure to the public. One is to develop new techniques to improve the containment capability of SLB. Many research projects are directed toward this end. Another option is to develop alternative disposal methods for LLW. During FY79 and FY80 the Los Alamos National Laboratory and its subcontractors at the University of Arizona, the University of Texas, Austin, and JRB Associates,Inc. studied the advantages of several alternatives to SLB,including deeper burial, mind cavities (geologic repositories for LLW) engineered structures, subsurface injection of liquid wastes, and seabed disposal. On the basis of technical, economic, and political considerations only two near-term alternatives seem realistic: deeper burial and mined cavities In this paper I can only briefly outline the alternatives. More complete discussions can be found in the cited references.

## DEEPER BURIAL

This alternative is similar to SLB except that the waste is buried deeper. While trench size may vary, depending on site characteristics, usually trenches about 20 m deep, 10-20 m wide, and a few hundred meters long should be sufficient. Engineered caps 5-10 m thick are an integral part of the disposal system, as are liners, sumps, and drain systems (1,2). Trench depth will depend on local geology, hydrology, and the type of equipment used. In general, the deeper the trench, the larger the volume of waste that can be buried for a given surface area. But side slope stability may limit depth.

Ideally, the waste is above the local water table and infiltration of precipitation is reduced by carefully designed trench caps and wick systems - concentric layers of natural materials, such as sand and gravel, that "wick" moisture away from the waste (3,4,5). The major advantage of increased depth of burial are that the effects of plant and animal intrusion and of surface erosion are significantly reduced, and that most shallow excavation activities will not penetrate deeply enough to expose the waste (1,6).

Deeper burial does, however, place the waste closer to the water table. For many potential sites, especially in the western United States, the local water table is sufficiently deep that ground water will not be an important factor in trench design (7). In areas of high precipitation the waste should be placed above or entirely below the zone of water fluctuation (8) and in rock units having higher permeabilities than the trench/cap system (1,9). If the waste must be below the water table, wick systems, which are effective only under unsaturated conditions, are out of the question. In this instance, more reliance must be placed on trench liners and radionuclide migration barriers, and on waste packages.

All the technology necessary for site construction, waste loading and operation is currently available.

## MINED CAVITIES

The mined cavity option involves placing the waste in excavated underground rooms at depths of 100-300 m (10). These are essentially geologic repositories for LLW. While considerably more expensive than SLB or deeper burial, this alternative is especially attractive for the diposal of some high-activity wastes, such as reactor resins and irradiated components.

Probably the most important aspect of mined cavity disposal is site selection in the proper host rock (8,11). Site selection requires geologic, hydrologic, and rock mechanic studies before a disposal site can be established (12). In general, favorable rock types are plutonic rocks (such as granite), basalt, limestone, and tuff (7,10). Shale and salt seen less favorable but, in some areas, may be acceptable. These rocks are more mechanically safe, environmentally stable, and impermeable than sandstones and metamorphics. However, if the disposal site is located above the water table, sandstones may be suitable. We do not recommend using existing mines (operational or abandoned) for waste disposal, as rock properties may not be optimum and there is always the danger of abandoned mines or stopes being reopened as a result of economic pressures. In addition, the ground may be unstable in previously mined areas, ventilation may be more difficult, and access routes may be long and impracticable (10).

Much of the required research in this area is already being conducted under the high-level waste (HLW) geologic repository programs and is immediately applicable to mined cavities for LLW (7,13). In addition, because of the lower thermal loading and shorter half-lives of LLW, the requirements for a mined cavity are less restrictive than for the geologic repository (11). Some candidate sites rejected by the HLW programs may be suitable for LLW. Many suitable sites are available in all regions of the country. Marginal localities can be discarded because a sufficient number of good sites exist (10).

Major disadvantages of mined cavities are the higher costs of site selection, construction, operation, and site closure (10).

## ENGINEERED STRUCTURES

Above-ground or slightly below-ground engineered structures are probably not acceptable as a disposal method but may be useful for interim storage of some LLW, such as irradiated components. Unless otherwise noted, the following is referenced to work performed by the University of Arizona for the Los Alamos National Laboratory.

The waste can be more easily monitored and, if necessary, cooled for short time periods. Because storage buildings can be completely engineered for specific functions site requirements are not as strict as for SLB or any of the alternative disposal methods (8). However, geologic and hydrologic investigations will be required to define design criteria, site monitoring programs, and accident response procedures. If long-lived radionuclides are present the waste may require moving, after some reasonable time period, to less accessible disposal areas ( a deeper burial trench or mined cavity, for example).

While in storage, the waste will be available for recovery of any desired materials. In future relocation of the waste, the latest state-of-the-art techniques can be used. However, deterioration of the waste matrix and containers may make removal more hazardous than the initial emplacement. Relocation will also increase final disposal costs.

As the storage buildings will be designed to withstand any expected earthquakes, tornadoes, and so forth, catastrophic releases are not anticipated. However, slow loss of structural integrity through time may result in slow releases of radioactivity directly into the biosphere. Another problem is that the waste will be accessible to unauthorized intrusion by man. Thus the site can never be decommissioned and strict site control measures must be maintained throughout the hazardous lifetime of the waste.

Several foreign countries are using engineered structures for temporary storage and aging of wastes before final disposal (16,17,18,19).

## WELL INJECTION

Many wastes are liquids, and solidification may increase their volume, as well as require off-site disposal. This alternative is a method for on-site disposal of liquid wastes. Three techniques are currently in use. Fluid injection involves injecting liquid waste through a disposal well into a permeable host rock,often at depths of a kilometer or more (8). Injection may be by pumping or by gravity flow (9,20). The host rock must have high porosity and permeability to avoid fracturing and bounded above and below by impermeable strata (21,22,23).

The hydrofracturing technique is similar, but the waste is mixed with a grout, which eventually hardens. The host rock is usually a well-bedded shale. Horizonal fractures are intiated with a small slug of water at a pressure exceeding in-situ rock strength, followed by injection of the waste/grout mixture which extends the fractures, resulting in a thin grout sheet a few hundred meters across (8). After several injections the well is cemented off and a higher level is developed (24, 25, 26). Liquids that are formed as the grout cures can be pumped back to the surface for reuse.

Liquid waste/grout mixtures can also be injected into specially constructed caverns. The caverns can be excavated by standard mining methods. The waste is prepared in a fashion similar to that for hydrofracturing, then slurried down an access shaft (9,20).

The extreme mobility of liquid wastes require that strict site selection criteria be established and waste emplacement procedures be carefully followed. Monitoring wells must be drilled to determine the limits of fluid migration. Retrievability is, of course, impossible.

The Soviet Union uses well injection regularly (27) and Oak Ridge National Laboratory has extensive experience in hydrofracturing (26). Cavern injection is under investigation in the Federal Republic of Germany (28). Considering the current trend in this country toward solidification and burial of liquid wastes, this alternative does not seem particularly attractive at this time.

## SEABED DISPOSAL

Seabed disposal of LLW involves wastes treatment and packaging, followed by dumping the waste containers over a specified deep sea disposal area. The containers free-fall to the ocean floor.

Little is known about the seabed as a disposal medium and extensive investigations on the sorptive properties of pelagic sediments, ocean currents, and food chains are required before a suitable site can be selected (29). Expensive port facilities and specially equipped ships will be needed. Thus seabed disposal is not a near-term option.

Several foreign countries having limited land area use the seabed as a waste disposal site (18,30,31). Between 1946 and 1962, when land disposal came into general use, the United States dumped much of its waste into the ocean; then the practice of ocean dumping decreased from 1962 to 1970 (32). Ocean disposal is currently under jurisdiction of the Environmental Protection Agency, which requires demonstration that no alternative disposal methods exist before a license can be issued (33). Many forms of land disposal, including those discussed in this paper, do exist.

A considerable amount of research on seabed disposal is being conducted in foreign countries (16,18,30,31,34) and subseabed disposal of HLW is under investigation in this country (7,9). While research for the U.S. HLW program is somewhat extravagant for LLW, all foreign and domestic research in this area is directly applicable. We therefore suggest that no new research for seabed disposal of LLW is necessary.

## RESEARCH NEEDS

We have identified two disposal methods that seem reasonable as near-term alternatives to SLB. These are deeper burial and mined cavities. However, before these options can be implemented, further research in several areas is still required. These research needs are outlined below.

### Research Needed To Implement the Deeper Burial Alternative

1. Identify monitoring techniques to measure water movement through inhomogeneous media (jointed, fractured, bedded rocks).

Several site-specific studies along these lines are being conducted by national laboratories ( in tuff at Los Alamos and in shale at Oak Ridge) in support of SLB. Analogous research for the HLW programs is being performed by universities for the Nuclear Regulatory Commission (NRC) and by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project at the Nevada Test Site (NTS). This work must be applied to deeper burial.

2. Identify possible chemical reactions that may occur under various oxidation/reduction and pH conditions in a deeper trench.

Generic research in this area is being conducted by Brookhaven National Laboratory (BNL). New research along these lines does not seem warrented at this time.

3. Determine possible migration rates and controlling pathways for radioactive gases, such as tritium, radioactive carbon dioxide and methane, and probably krypton and iodine. Potential releases must be related to pressure gradients, thermal gradients (for gases dissolved in trench water), and soil permeability.

Again, BNL is already involved in this kind of work. Results of work performed under the Remedial Action Program for uranium mill tailings is immediately applicable, but these studies must be applied to deeper burial.

4. Study special backfill materials to maintain desired chemical conditions in the trench region.

NRC is supporting research in this area at the SLB site at Maxey Flats, Kentucky. Also, similar studies are underway in the Federal Republic of Germany. These activities should be applicable to deeper burial.

5. Test the use of reinforced fabrics in trench caps as to effectiveness and life exceptancy.

The best materials to use in trench caps seem to be natural materials, but fabrics may be useful to provide short-term stability until the sand, clay, and gravel have achieved sufficient consolidation. Life expectancy estimates can be readily obtained from the manufacturer. Research to test various fabrics is currently underway at Maxey Flats and at the University of Arizona.

6. Test different slope stabilization techniques to determine which ones will allow for maximum slope of trench walls.

This information is site-specific, and slope stability will depend on the host rock, trench depth, and prevailing ground conditions. There is a considerable amount of experience at current SLB facilities. Any additional needed information should be readily available from mining and construction companies.

7. Determine sorptive capacity for radionuclides in soil/waste solution systems.

Investigations to address this question are being conducted at Maxey Flats by the U.S. Geological Survey and at West Valley, New York by the New York State Geological Survey for the NRC. Sorptive studies using liquid waste from Los Alamos and soils from Maxey Flats, Sheffield, Illinois, Beatty, Nevada, and Los Alamos are being performed by the Los Alamos National Laboratory.

8. Field testing to verify computer models for unsaturated flow.

Very little work is being done in this area. As part of a program to study advanced SLB technology at arid sites, Los Alamos is verifying an unsaturated flow model (WAFE). Small programs in Canada and at Hanford are investigating the problem, but more work is clearly needed.

9. Obtain experimental data on hydraulic conductivity as a function of saturation and porosity.

These studies will require considerable time in drilling and performing in situ hydraulic conductivity experiments, such as slug and packer tests.

10. Field test wick systems (unsaturated conditions).

Los Alamos is currently investigating various wick system designs as part of a program to develop advanced SLB technology.

11. Test various waste matrix materials for leach rates.

Leach rates of waste matrices are being extensively studied by the HLW program in this country and by LLW and intermediate-level waste programs in Europe. Results from these investigations will be applicable.

## RESEARCH NEEDED TO IMPLEMENT THE MINED CAVITY ALTERNATIVE

1. Modeling of fluid flow into storage rooms or tunnels under unsaturated conditions for various input parameters, such as water content, unsaturated hydraulic conductivity, infiltration rates, and source terms.

Saturated flow into mines has been studied extensively, but little has been done to address the problem of unsaturated flow. The only obvious analogous studies in the geologic repository program are related to the NNWSI project at NTS. This work is quite generic at this time.

2. Determine the economic and cost/benefit factors for mined cavities as a function of size, host rock, mine layout, and type of equipment used.

Several design studies have been, and are being, performed in relation to the geologic repository for HLW. The repository will be much deeper than a mined cavity for LLW, and design criteria are much more stringent. Thus costs will have to be scaled down before being applied to a mined cavity.

3. Modeling of migration pathways for various radionuclides most likely to cause exposure to man.

This work has essentially already been done by the Office of Nuclear Waste Isolation (ONWI), the national laboratories, and many universities. The information is scattered throughout the technical literature and must be pulled together and evaluated.

4. Characterize variations in horizontal and vertical permeabilities as a function of depth in candidate host rocks (granite, basalt, tuff, limestone, shale) and identify possible relationships between bed or flow thickness and permeability.

We have been unable to find any previous or current research in this area. The amount of information required is quite extensive and there is a very limited data base to draw from.

5. Investigate changes in permeabilities of surrounding rocks caused by drilling and blasting and by rig drilling.

This question is being addressed by the University of Arizona for NRC.

6. Measure permeabilities of large sections of rock.

Lawrence Berkeley National Laboratory is conducting these investigations.

7. Evaluate various potential entry seal materials and configurations with reference to long-term stability, behavior under field conditions, physical and chemical properties, and the effect of placement and seal geometry on surrounding rocks.

This work is already in progress. The initial work, as applied to geologic repositories, is being performed under ONWI. Confirmatory research supported by NRC is also underway. The results of this research are applicable to mined cavities for LLW.

8. Evaluate change in rock chemistry and possible long-term effects of mining operations (for example, oxidation processes and the effects of bacteria and algae introduced into the mine during operation).

This issue is being addressed by BNL and no new work seems required at this time.

9. Determine <u>in-situ</u> rock characteristics without extensive drilling.

The delopment of improved geophysical techniques for use in determining rock quality and rock mass classification is being done by the University of Arizona for NRC.

# SUMMARY

During FY79 and FY80 the Los Alamos National Laboratory and its contractors at the University of Arizona, the University of Texas, Austin, and JRB Associates, Inc. performed a preliminary evaluation of several alternatives to shallow land burial. These alternatives include deeper burial, mined cavities, engineered structures, well injection of liquid waste, and seabed disposal. We identified two alternatives as reasonable near-term disposal options: deeper burial and mined cavities.

The Low-Level Waste Management Program would do well to consider a combination of alternatives rather than disposing of all LLW in the same manner. For example, most LLW could be buried in deeper trenches, while high-activity wastes and those containing longer-lived radioniclides could be disposed of in mined cavities for LLW. Waste having potential resource value and some other wastes could be temporarily stored in engineered structures until final disposition has been decided.

Research needed to implement the deeper bruial and mined cavity alternatives have been identified. Some of this work is currently in progress, some is being conducted for other programs and must be applied to LLW, and some is new.

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