CHARACTERIZATION OF SITES FOR LOW-LEVEL WASTE DISPOSAL FACILITIES

R. J. Lutton

U. S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi 39180Summary

Characterization of a candidate site to establish its suitability for low-level waste disposal requires careful evaluation of numerous site parameters. Parameters may be grouped for purposes of site definition, hydrological analysis, facility engineering, and monitoring. Each group has importance in the evaluation of the site for containment or in the design and construction of secure facilities. With sufficient attention to the environment, the media, and the construction materials, the problems encountered in past disposal operations will be avoided in the future.

Background

Basic documents have been prepared recently by the U. S. Nuclear Regulatory Commission (NRC) for licensing and regulating land disposal operations for low-level waste (LLW).^{1,2} Before a license can be obtained, the NRC must be convinced that the facility meets both performance objectives and prescriptive requirements. Performance objectives emphasize the NRC's overall goal of protection of the public health and safety. Specific performance objectives emphasize the protection of workers and the general population during operation of the facility, minimization of the need for continued active care and maintenance, avoidance of exposure of the waste or of inadvertent intrusion into the waste after closure, and avoidance of excessive releases of radionuclides from the waste to the environment (particularly the ground water). Prescriptive requirements include more specific characteristics or minimum technical requirements for assuring that the performance objectives are met.

The present paper summarizes work nearing completion at the U. S. Army Engineer Waterways Experiment Station on site characterization and monitoring for LLW disposal.³⁻⁵ Other reports are in preparation on trench design and construction and on geotechnical quality control.

Site Suitability

Important site suitability requirements have been established.¹ The more pertinent physical requirements affecting the planning of site investigations are that the site media be: (a) capable of being characterized, modeled, and analyzed; (b) well drained and free of surface flooding; (c) unaffected by ground water fluctuation and intrusion. The usual setting is expected to be above the water table, but exceptional cases may involve burial of waste below the water table. Sites need to be selected and facilities designed to minimize migration of radionuclides for at least 100 and 500 years after termination of operations for Class A and B waste and Class C waste, respectively.

Construction

The NRC expects the LLW site media (Figure 1) to have the primary role in minimizing the migration of radionuclides. Thus, site selection and media characterization are particularly important. However, the disposal units (trenches) placed into the

Figure 1. Main features of a LLW facility.

site media are to be engineered to provide secondary stability as well. Past disposal units have ranged in size from $5 \times 5 \times 5$ -m pits to long trenches over 50 m in width and 15 m in depth. Figure 2 illustrates schematically the important components of a disposal unit.

Figure 2. Components of a LLW disposal unit.

A granular drainage layer is an optional feature that has in the past often been placed first at the bottom of the trench, especially in large disposal units. Rain and snow melt water trapped in the burial trench during operations as well as percolate that has passed through the cap of the disposal unit after closure can be pumped from a sump in the system.

Waste has in the past been placed in the trench in a variety of containers and forms--steel drums and large liners, cardboard or wood boxes, plastic bags, and irregular metal parts and scrap. In the future wooden and paper boxes and plastic bags will be prohibited. As much as 35 percent of the trench volume is composed of soil placed during operations as backfill and intermediate cover.

After completion of the filling of the trench, the unit is covered with a final cap. This cap is usually composed of a fine-grained soil that permits only slow, infrequent infiltration, if any at all.

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Outward slopes (Figure 2) on the flanks facilitate runoff of precipitation. A synthetic membrane may be incorporated as a barrier element of the cap. The trench cap is usually topped with vegetation to reduce erosion and to promote evapotranspiration of infiltrated water.

Past Problems

The emphasis currently placed on site characterization¹ has evolved partly from experiences with problems at prior LLW disposal sites as well as from experience in disposal of other (nonnuclear) wastes. Salient problems centered in the site media are schematically represented in Figure 3. The first type of

Figure 3. Some problems within site media.

problem involves unexpected leakage of radionuclides through the site media from the disposal unit. The preferred paths for migration may follow inconspicuous but highly permeable layers, but paths along fractures in the rock or soil are also common. For example, the rate of ground-water migration in fractured glacial till is believed to exceed by more than 100 fold that in unfractured till. A second and very common problem of intrusion of ground water into the waste is usually very serious since it places the radionuclides directly in that important pathway. The key to the severity lies in the seepage velocity; stagnant ground water poses little or no threat. The third problem, the bathtub effect, reveals an important contradiction of the common assumption that low-permeability media are most suitable. Disposal units in tight shales can fill with percolating water like bathtubs. Continued rising causes contaminated water to spill over the low side and release radionuclides.

Three other problems are more closely associated with construction practice than a consequence of specific site setting and media (Figure 4). Caps constructed of pervious material or suffering from

Figure 4. Some problems within disposal unit.

little or no quality control may permit water to percolate from the surface into the waste-filled trench. Where this inflow is excessive, the migration of radionuclides downward to the water table is usually increased.

An ineffective cover can also permit radioactive gases to escape to the atmosphere. However, experience in disposal of municipal waste has revealed that covers that block direct venting occasionally create other problems by forcing the gas to move laterally into site media. The final problem identified in Figure 4 involves poor construction practice that culminates in settlement and subsidence in the waste and disruption of the cap. In extreme cases and where maintenance is neglected, depressions form, water ponds, and the trenches may receive excessive amounts of percolation.

Site Characterization

The potential for problems such as mentioned above makes it imperative that site characterization be emphasized early in the facility life cycle. The usual site selection investigations are scheduled in a preliminary stage. Detailed subsurface and environmental investigations (site characterization) mostly follow site selection and are directed at the evaluation of the selected site and final approval or rejection. Characterization parameters can be grouped according to their applications as indicated below.

Site Definition

Certain parameters are needed for defining the geometry and nature of geological strata and material zones of the site. These parameters enter into the analyzing and engineering of the site and facility and, therefore, have encompassing importance.

Particularly important parameters among this group are the following:

STRATIGRAPHY	SOIL/ROCK CLASSIFICATION
GEOLOGICAL STRUCTURE	WATER CONTENT
UNIT BOUNDARIES	MATERIAL COLOR
MATERIAL DENSITY	RESISTIVITY

These parameters are used to develop details of the immediate site as well as to relate site conditions and details to the surrounding regional picture. Definition parameters are mostly evaluated using geological techniques and interpretations reinforced with material index tests and geophysical surveys (resistivity, seismic, and nuclear methods).

Hydrological Analysis

The most important part of characterizing a LLW site usually amounts to the detailed documentation of the flow systems of ground water and gases with potential migration of radionuclides. The migration from the disposal unit mainly involves two separate phenomena: first, the mass movement along with the diffusion of the solutes themselves, and second, the retardation of the solutes by chemical processes taking place along the migration path. The following parameters are particularly important:

WATER SYSTEM	SOLUBLES AND ORGANICS
HYDRAULIC CONDUCTIVITY	PORE WATER AGE
HYDRAULIC POTENTIAL	SEEPAGE VELOCITY
DISPERSION	EFFECTIVE POROSITY
DISTRIBUTION COEFFICIENT	ANISOTROPY
ION EXCHANGE CAPACITY	FLOW DIRECTION

The hydraulic conductivities and hydraulic potentials of unsaturated as well as saturated zones are needed. Other parameters are components of the water balance, frequently needed to understand ground-water flow and to estimate percolation according to the following equation:

$$\text{PERCOLATION} = \text{PRECIPITATION} - \text{RUNOFF} \\ - \text{EVAPOTRANSPIRATION} - \text{CHANGE IN STORAGE}$$

Some hydrological parameters are evaluated by field testing such as pumping tests, tracer studies, and well point observations. Others can be evaluated by laboratory tests such as for hydraulic conductivity and water content. Methods of testing and documentation are identified elsewhere.⁴

Facility Engineering

Review of past operations for disposal of hazardous wastes (including LLW) reveals that excavation, backfilling, and burial have often been conducted in an expedient manner with only modest attention to engineering. With greater emphasis on secure burial over long periods of time, greater attention is now being directed to developing the facility and conducting the routine operations in an engineered manner. Accordingly there is a need for the following engineering parameters as a part of site characterization:

MATERIAL INDICES	SWELLING-SHRINKING
STRENGTH	CORROSIVITY
COMPACTION RELATION	SURVEYED LOCATIONS
ERODIBILITY	

The evaluation of engineering parameters is fairly straightforward in the manner of geotechnical investigations for other types of construction. The testing of samples recovered from boreholes is the usual approach. Standard and state-of-the-art methods are identified elsewhere.⁴

Site Monitoring

Regardless of useful redundancy in design and the predictions developed in the hydrological analysis, there will remain more or less uncertainty as to the possible leakage and migration of radionuclides. Geological settings and combinations of design features are so complicated as to contain irregularities or unrecognized conditions that may alter the expected containment. For these eventualities, the monitoring system is essential. Thus, if radionuclides migrate unexpectedly, they should quickly be recognized as a threat so that appropriate steps may be taken. The most effective monitoring builds upon a basis of background measurements; thus monitoring parameters are measured from the site evaluation stage through the institutional control phase of the facility life cycle. The following groups of monitoring parameters are particularly important:

RADIOLOGICAL CONSTITUENTS	GROUND WATER CONSTIT
GASEOUS CONSTITUENTS	SURFACE WATER CONSTIT

Measurement of these groups of parameters to establish a monitoring baseline is conducted in the laboratory or in the field and should follow standard test methods.⁴

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