CHARACTERIZATION OF SITES FOR LOW-LEVEL WASTE DISPOSAL FACILITIES

R. J. Lutton
U. S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi 39180

Summary

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). 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. Other reports are in preparation on trench design and construction and on geotechnical quality control.

Site Suitability

Important site suitability requirements have been established. 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 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.

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 characterization 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 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 3. Some problems within site media.

Figure 4. Some problems within disposal unit.
Particularly important parameters among this group are the following:

- **STRATIGRAPHY**
- **GEOLOGICAL STRUCTURE**
- **UNIT BOUNDARIES**
- **MATERIAL DENSITY**

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**
- **HYDRAULIC CONDUCTIVITY**
- **HYDRAULIC POTENTIAL**
- **DISPERSION**
- **DISTRIBUTION COEFFICIENT**
- **ION EXCHANGE CAPACITY**

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**
- **COMPACTION RELATION**
- **SURVEYED LOCATIONS**

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 CONSTITUENTS**
- **SURFACE WATER CONSTITUENTS**

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

**References**


