Lockheed-Martin Idaho Technologies Company
Idaho National Engineering and Environmental Laboratory

INEEL/CON-97-01171
CONF-971033--

Design and Operational Considerations of United States Commercial Near-Surface Low-Level Radioactive Waste Disposal Facilities

National Low-Level Waste Management Program

Sandra M. Birk, October 1997

Work supported by the U.S. Department of Energy, Office of Environmental Management, under DOE Idaho Operations Office Contract DE-AC07-94ID13223.

DISCLAIMER

DISCLAIMER

Background

In accordance with the Low-Level Radioactive Waste Policy Amendments Act of 1985, states are responsible for providing for disposal of commercially generated low-level radioactive waste (LLW) within their borders. LLW in the United States is defined as all radioactive waste that is not classified as spent nuclear fuel, high-level radioactive waste, transuranic waste, or by-product material resulting from the extraction of uranium from ore. Commercial waste includes LLW generated by hospitals, universities, industry, pharmaceutical companies, and power utilities. LLW generated by the country's defense operations is the responsibility of the Federal government and its agency, the Department of Energy.

Six commercial LLW disposal facilities operated in the United States between 1962 and 1997. All are now regulated by states under agreements with the U.S. Nuclear Regulatory Commission (NRC). Such states are referred to as Agreement States. Three of the sites have been closed since mid-1970: West Valley, New York (1975), Maxey Flats, Kentucky (1977), and Sheffield, Illinois (1978). The Beatty, Nevada site closed at the end of 1992. The Barnwell, South Carolina site has plans to remain open to nationwide LLW generators for the next several years. The Richland, Washington site receives LLW from only generators in the Northwest and Rocky Mountain States. In addition, proposed disposal sites are in various stages of development in California, Texas, North Carolina, and Nebraska.

The commercial LLRW disposal sites discussed in this report are located near:

- Sheffield, Illinois (closed)
- Maxey Flats, Kentucky (closed)
- Beatty, Nevada (closed)
- West Valley, New York (closed)
- Barnwell, South Carolina (operating)
- Richland, Washington (operating)
- Ward Valley, California, (proposed)
- Sierra Blanca, Texas (proposed)
- Wake County, North Carolina (proposed)
- Boyd County, Nebraska (proposed)

While some comparisons between the sites described in this report are appropriate, this must be done with caution. In addition to differences in climate and geology between sites, LLW facilities in the past were not designed and operated to today's. In the past, disposal sites accepted liquids, loosely packaged waste, and higher concentrations of radionuclides which were not immobilized. The experience from these operations is now reflected in stricter standards for LLW disposal at the Federal and Agreement State level.

This report summarizes each site's design and operational considerations for near-surface disposal of low-level radioactive waste. The report includes:

- a description of waste characteristics
- design and operational features
- post closure measures and plans
- cost and duration of site characterization, construction, and operation
- recent related R&D activities for LLW treatment and disposal, and
- the status of the LLW system in the United States.

Waste Characteristics

Over the years, disposal limits for volume, activity, and packaging have evolved with regulatory changes. The volume and activity level of waste disposed of at the four closed facilities in Table 1 shows that the Beatty, Nevada facility received the most volume while Maxey Flats, Kentucky received the most activity. Following the description of waste disposed at now closed sites is a description of the waste acceptance criteria for the operating and proposed disposal facilities. The reader should note that some of the criteria for proposed facilities are draft and considered preliminary.

Closed LLW Disposal Sites

Sheffield, Illinois

Approximately 88,000 m^3 (3,100,000 ft^3) of LLW was disposed of in steel drums, fiberboard boxes and drums, and steel liners at the Sheffield site between 1966 and 1978 (DOE, 1994). Although the site operator was not required to keep an inventory of waste, studies (Nuclear Engineering Company, Inc., 1979) estimated the activity to be more than 2.257 E+15Bq (61,000Ci), consisting primarily of tritium, strontium, cesium, and cobalt

Maxey Flats, Kentucky

Approximately 140,000 m^3 (4.9 million ft^3) of waste, containing over 8.88 E+16Bq (2.4 million curies) of byproduct material, 431 kg (950 lb.) of special nuclear material, and 240,000 kg (533,000 lb.) of source material were buried at Maxey Flats from 1963 to1977 (DOE, 1994). The waste included tritium, plutonium, strontium, and gamma-emitting radionuclides. Uncertainty exists regarding the activity of the waste because much of the waste sent to the site was labeled mixed fission products (CRCPD, 1996). Most of the wastes were solids received in steel drums. Other packages included concrete and steel tanks, concrete vaults, and wooden and cardboard boxes. The materials included animal carcasses and tissue, paper, cardboard, wood, plastics, organic chemicals, clothing, protective apparel, laboratory glassware, obsolete equipment, ductwork, radiopharmaceuticals, plastic tubing, and rubble. Other materials included solidified liquids, shielding, filters, ion-exchange resins, activated metals, and evaporator sludge.

Beatty, Nevada

From September 1962 through December 1992, the site received a total volume of 139,500 m^3 (4,930,000 ft^3) of low-level radioactive waste, with a total radioactivity of approximately 2.65 E+16 Becquerels (715,000 curies) (U.S. Department of Energy, 1996). The radioactive waste received at the site was primarily solid or solidified materials, contaminated equipment, cleaning wastes, tools, protective clothing, gloves, and laboratory wastes.

West Valley, New York

From 1963 to 1975, about 66,553 m^3 (2.35 million ft^3) containing approximately 2.74 E+16 Bq (740,000 curies) were disposed of in the low-level radioactive waste portion of the West Valley site (DOE, 1994). The waste was received from a variety of sources including medical and academic institutions, industries, government facilities, nuclear power plants, waste brokers, decontamination companies, and the West Valley site operations. This portion of the site was licensed to accept three types of radioactive wastes: (1) by-product materials including tritium, carbon-14, cobalt-60, iodine-125, iodine-131, cesium-137, and americium-241; (2) source materials including thorium-232, uranium-238, and natural uranium; and (3) special nuclear materials including uranium-235, plutonium-238, and plutonium-239 (CRCPD, 1996). The majority of the waste was packaged in steel drums, wooden crates, and cardboard boxes. Filter sludge and filters packaged in 55 gallon drums are among the waste disposed of at West Valley.

Table 1. Estimated total volume, activity, and package type for wastes received at facilities that are no longer open for disposal.

Site	Volume	Activity	Package Type
Sheffield, IL	~88,000m^3 (3,100,000ft^3)	Estimated 2.257 E+15Bq (~61,000Ci) (primarily tritium, strontium-90, cesium-137, cobalt-60)	Wastes packaged in steel drums, fiberboard boxes, fiberboard drums, and steel liners.
Maxey Flats, KY	140,000m^3 (4.,900,000ft^3)	8.88 E+16Bq (2.4Mci) byproduct material 431kg (950lb) SNM 240,000kg (553,000lb) source material (Tritium plutonium, strontium, and gamma-emitting radionuclides)	Most of the wastes were solids received in steel drums. Other packages included concrete and steel tanks, concrete vaults, and wooden and cardboard boxes.
Beatty, Nevada	139,500 m^3 (4,930,000ft^3)	Approximately 2.65 E+16 Bq (715,000 Ci))	
West Valley, New York	66,553m^3 (2,300,000 ft^3)	2.74 E+16 Bq (740,000Ci) (By product material, source material, and special nuclear material)	Steel drums, wooden crates, and cardboard boxes. Filter sludge and filters in 55 gal. drums

Operating and Proposed Disposal Sites

Experience from closed sites has taught us a great deal about waste and how to package it. Evolving state and Federal regulations reflect what was learned from sites that have operated since the 1960s. Specific details for the criteria for each operating and proposed commercial low-level radioactive waste disposal facility can be found in A Comparison and Cross-Reference of Commercial Low-Level

Radioactive Waste Acceptance Criteria, published by the National Low-Level Waste Management Program (1997). Waste acceptance criteria from the following entities are included: U. S. Nuclear Regulatory Commission, South Carolina, Washington, California, Texas, North Carolina, and Nebraska. Standards are also included for sites operating in Utah and preliminary criteria for potential sites in Illinois, Pennsylvania, and New York. In most cases, states have adopted the NRC's waste acceptance criteria or adopted more stringent standards. No state has accepted lower standards than those defined by the Commission. A summary of the criteria follows.

Physical form, chemical form, and liquids limits

The NRC waste acceptance criteria are defined in 10 CFR 61.56. These criteria identify the allowable physical form of wastes as solids, absorbed liquids, and uncompressed gases. NRC's standard does not allow waste to exhibit explosive or gaseous reactions and restricts liquid limits to < 1% by volume for high integrity containers or < .5% by volume for other wastes. Some states allow absorbed liquids while others do not. Most states have adopted the NRC's criteria for chemical form and liquid limits. In some cases states have added additional restrictions on organic solutions.

Void space, concentration averaging, and packaging

In an effort to follow the NRC's directions to minimize void spaces, many states have adopted a <15% by volume void space for all waste unless placed in a high integrity container. While the NRC standard allows concentration averaging, many states do not allow this approach for sealed sources or filters encapsulated in solidification agents. All states adopted the NRC's standard to restrict cardboard or fiberboard packages.

Chelating agents, solidification media, and stability

The NRC standard states that any chelating agents >.1% must be reported. Some states have put limits on chelating agents at < 8% by weight and also may require stabilization of the wastes. The NRC requires that solidification media must comply with its Branch Technical Position on waste form. States have adopted this standard but have added specific waste forms acceptable at their individual sites. The NRC requires that Class B and C wastes be placed in a high integrity container or must be in a form that is inherently stable. All states have adopted the NRC's stability requirements and have in some cases, established more stringent standards.

Sorptive media, gas, and oil

The NRC allows sorptive media to absorb liquids. Generally those states that do not allow liquids have placed more stringent requirements on the liquids. The NRC standard is silent on oil, however most states have set standards to solidify oil if > 10% by weight. States have generally adopted the NRC standards of < 1.5 atm at 20 °C with a maximum radioactivity of 100 curies for gases.

Biological waste, pyrophorics, and source material

The NRC standards require that biological waste be treated to reduce pathogenic or infectious hazards. Most states have increased these standards to ensure wastes are placed in sealed liners layered with absorbent and double drummed. The NRC standard states waste must be treated or packaged to be non-flammable. States require this and further require that wastes cannot react violently with water, moisture, or agitation. The NRC standard is silent on restrictions for source material, but most states have adopted mass limits for source material.

Special nuclear material, package dimensions, and incinerator ash

The NRC does not establish waste acceptance criteria for special nuclear material, package dimensions, or incinerator ash. Most states have adopted mass limits for the special nuclear material isotopes of U-233, U-235, and plutonium. Package dimensions are largely based upon the specific site design and equipment available at the individual sites. Most states also require that incinerator ash be treated to be non-dispersible in air.

Dewatered resins, transuranics, and mixed waste

The NRC standard allows dewatered resins but is silent on transuranics and mixed waste. Most sites accept ion exchange resins and require that transuranics be evenly distributed. Finally, most sites do not accept mixed wastes, thus creating a problem for disposal for those generators of mixed waste.

Design and Operational Features

Facility designs and operational features vary depending on the characteristics of the site, but they all have one thing in common. They use a series of barriers to keep water from entering the disposal area, coming in contact with the waste, and transporting dissolved radioactive material.

Closed LLW Disposal Facilities

Initially, waste disposal practices were similar to landfill operations that were directed towards occupationally safe and efficient site operation. Little attention was given to the long term effects of these practices or the hydrology of a site. (Prudic and Dennehy, 1987, Murray, 1994). Operations were similar at all of the original sites. The land was cleared and regraded, and long shallow trenches were excavated for the disposal of LLW. When the trenches were filled, operators covered the trench with excavated soil and compacted the material. The area around the trench was usually regraded to prevent runoff. At some sites the water table below the trenches came into direct contact with the buried waste (Prudic and Dennehy, 1987). Following closure, significant efforts have been made to cap these trenches to prevent migration of nuclides from the sites. No one from the public has received any measurable dose.

The West Valley and Maxey Flats sites all experienced leaks and were closed (Murray, 1994). Failures noted (NUREG/CP0028, 1982-3) include erosion by surface water, subsidence that allowed water to percolate into the waste, and the "bathtub effect". The bathtub effect occurs when water percolating through the trenches exceeds percolation out of the floors and walls causing the trench to fill up with water, corrode waste containers, and overflow into the environment. The bathtub effect was noted at West Valley and Maxey Flats.

Richland, Beatty, and Barnwell did not experience these design problems. Problems at these sites involved site contamination when poorly packaged wastes arrived (Murray, 1994). Based upon these incidents, the three states became concerned about the injustice of receiving the entire nation's waste which gave rise to the Low-Level Radioactive Waste Policy Act of 1980.

Operating and Proposed Facilities

Today's sophisticated trench designs with improved covers, capillary barriers, and drains resulted from knowledge gained from previous waste disposal practices. The new designs are intended to minimize contact of water with the wastes, however long term performance of these designs is untested, thus monitoring is still needed at all sites to assure that any release of radionuclides to the environment is held within prescribed standards. Technologies used in disposal sites currently in operation are restricted to modified shallow land burial methods. The Barnwell facility uses layers of impervious clay to minimize infiltration of rainfall and groundwater. The Hanford facility, located in an arid region, simply disposes of waste at a deep level (8 feet, >5 meters for Class C wastes). Proposed technologies for disposal in high rainfall areas are using aboveground vaults with multilayered-engineered soil caps that will place several moisture barriers between groundwater and rainfall sources and the waste packages. In arid locations, shallow land burial is still proposed, although the Texas site design calls for using concrete vaults for the placement of waste in the trench. Barnwell, South Carolina has recently changed its waste package requirements for concrete vaults as well. A description of the design and operational features for operating facilities follows (CRCPD, 1996).

Barnwell, South Carolina

The Barnwell facility uses shallow land burial technology. Because the Barnwell facility is located in a region of high annual precipitation. The trench is constructed with a monitoring system and moisture barriers to collect and remove leachate. The floor of the trenches slopes to one side with a drain running the length of the trench. A layer of sand is placed on the bottom of the trench to ensure that water entering the trench drains to the sump for collection. When the trenches are filled with waste, sand is used to fill the voids between packages. Soil placed over the backfilled trench, a layer of clay, and a layer of soil and vegetation provide the cap for the trench.

Narrow trenches are excavated for waste with higher radioactivity levels. The trench floor is lined with gravel to provide ready drainage. The waste is placed in the trench and backfilled with clay, after which a cap similar to that used for the larger trenches is placed on top of the trench.

Monitoring of the air on the site boundary and monitoring of the shallow levels of groundwater are part of the environmental monitoring system. Potable water from the deep aquifer 107 m (350 feet) is also sampled.

Richland, Washington (Northwest Compact Region)

The Hanford commercial low-level radioactive waste burial site in Washington disposes of LLW for the Northwest and Rocky Mountain compact regions. The Hanford disposal site is located in an arid region where the average rainfall is about 6 inches per year. The site uses shallow land burial technology, which consists of an excavated trench, located a suitable distance from ground and surface water and from the site boundaries. The Hanford site consists primarily of soil, sand, gravel, and boulders. New trenches are excavated to a depth of 14 meters (45 feet). Waste is placed in the trench up to 8 feet of the original grade level. The trench is then backfilled using the excavated material and compacted to the original grade level. A soil cap placed over the trench and a layer of gravel and cobble is placed over the cap material to prevent erosion and discourage burrowing animals.

Ward Valley, California (Southwestern Compact Region)

The State of California identified an arid site in Ward Valley in the Mojave Desert. Shallow land burial will be the technology used at the Ward Valley site for LLW disposal. Four trenches are proposed for disposal of Class A waste and a single trench is planned for the disposal of Class A wastes in excess of 30R/Hr, Class B, and Class C wastes. Because most Class A waste is not currently required to be stabilized, the trenches will be sized such that backfilling can begin soon after the waste is placed in the trench, thereby minimizing the exposure time of the waste to the environment. The Class A trenches will be excavated to a depth of 18.3 meters (60 feet). Forty feet of waste will be placed in the trench. The filled trench will be backfilled with 6 meters (20 feet) of soil, which brings the level in the trench back to grade. An additional 1.2 meters (4 feet) (average) of soil will be placed on the trench above grade level. The Class B and C trench will be excavated to a depth of 12.8 meters (42 feet). Twenty two feet of waste will be placed in the trench. Following placement of an engineered cap, the trench will be backfilled to grade level with native soil. All trenches incorporate the use of a gravel mulch and vegetative layer to minimize infiltration. An additional 1.2 meters (4 feet) (average) of soil will be placed on the trench above the grade level. Earthen berms will be located on the up-gradient side of the facility as a flood control measure.

The Ward Valley disposal facility will be located on a 1,000-acre site. The disposal facility will be located on 70 acres of the site, with the remainder of the land acting as a buffer zone. An 8-foot chain link fence topped with barbed wire will surround the disposal area. A hardware cloth skirt will be used to discourage burrowing animal intrusion. The hardware cloth will extend below and above grade.

The facility will be equipped with a meteorological and air quality station and up to eleven groundwater-monitoring wells. A dimensional vadose zone monitoring network encircling the monitoring devices will also be situated at several locations on the site and on the site boundary. The monitoring systems will provide data concerning release or migration of radionuclides from the controlled areas.

Sierra Blanca, Texas

Texas has identified a site in Hudspeth County in western Texas. The disposal concept identified for use at the Texas site consists of using concrete canisters in an excavated trench. Class A waste will be disposed of separately from the Class B and C wastes. Waste that is sent to the site for disposal will be placed in a steel reinforced concrete canister, which will be placed in a 3.6 meter (12 feet) deep trench. When the canister is full, cement grout will be pumped in to fill voids and a 13.5-inch thick concrete lid will be bolted onto the top of the canister. Once a row of the canisters have been filled, sealed, and inspected, a specially graded soil mixture will be placed over the canisters. The soil mixture has the intended purpose of directing moisture away from the waste. A 1.8 meter (6 feet) engineered cap will prevent rainfall from entering the disposal unit. The engineered cap will include monitoring sensors that will be used periodically as specified in the license agreement to detect leakage from the canisters. If a leak is detected, the modular design will allow for retrieval of the leaking canister.

The canisters will be cylindrical, 2.7 meter (9 feet) tall and about 2.4 meter (8 feet) in diameter. The walls will be about 10 inches thick and constructed of steel reinforced concrete. The canisters will have a 13.5-inch thick floor and lid. The canisters are designed to be watertight and to withstand an earthquake of at least a magnitude of 6.4 on the Richter Scale (.3 g/sec.)

The site will incorporate a series of trenches designed to channel storm runoff water away from the disposal trenches to a retention pond.

Wake County, North Carolina (Southeast Compact Region)

North Carolina is proposing an engineered above grade disposal concept. Waste containers will be placed in concrete overpacks. When full, the overpacks will be sealed with cement grout. The concrete overpacks will then be placed in reinforced concrete disposal modules on the bottom floor of the disposal facility. The bottom floor consists of a multilayered system, including a layer designed to drain moisture away from the waste packages (compacted sand), a layer of plastic liner material to block moisture infiltration from beneath, a layer of clay, and a layer of low-permeability soil that further blocks moisture infiltration from beneath the facility. The waste packages will be covered above by a multilayered cap system, which includes a concrete roof, a polymer seal, lower drain material (sand), a layer of low-permeability soil, a layer of clay, a plastic liner, a drainage layer (sand or gravel), and a layer of soil and vegetation.

The disposal facility will use a monitoring system designed to detect and collect potential infiltration from each individual disposal module. Several monitoring wells will be drilled to monitor infiltration of waste material into the water table and subsequent migration of infiltrate through the groundwater system.

Boyd County, Nebraska (Central States Compact Region)

Nebraska plans call for abovegrade reinforced concrete vault, which will be covered by an engineered soils cap. The vaults will be parallel with an access corridor between the rows. A moveable building located between two vaults will provide access to the two facing vault cells for truck off-loading. Class A waste will be handled with forklifts, inspected, and placed in a cell designated for Class A waste. Overhead cranes will be used to unload and place waste in the cells when the packages are too heavy or large for a forklift. Class B and C waste will be placed in separate vaults from the Class A waste. Class B and C waste will be placed in vaults through removable roof panels. Once the Class B and C vaults are filled, a slab of concrete will be roller compacted over the roof to provide a moisture barrier.

An engineered soils cap will be placed over the concrete vault to provide additional water barriers. The cap will consist of a geotextile fabric layer, a layer of impervious clay, a layer of concrete, and five feet of topsoil. Layers of sand will be placed above moisture barriers to direct moisture away from the vault area. A system consisting of groundwater monitoring wells, surface water collection system monitoring, and air monitoring will be put in place. Also, vegetation and wildlife will be collected for radiological analysis.

Pennsylvania (Appalachian Compact Region)

Although Pennsylvania has not selected a disposal site, the state adopted certain design and operational features for any new facility. Because Pennsylvania has a shallow groundwater level and high annual rainfall, the proposed disposal technology consists of an earthen-covered abovegrade vault. The waste containers will be placed in a concrete overpack. When the overpacks are filled, the containers will be grouted in place. The concrete overpacks will then be transported by truck to the disposal unit. The concrete overpacks will be placed in a concrete vault. Class B waste will be situated in the center of the vault and

Class A waste will be placed along the outer walls. The void spaces between the overpacks will be backfilled with sand, and a concrete cover will be poured in place. These activities will be performed inside a moveable building that will protect the processes from weather. Once the vault is filled and the concrete cover is in place, the building will be moved to the next disposal vault. Class C waste will be handled similarly, but disposed of in a separate area.

The vaults are designed to direct any leakage from the controlled structures into a trough that will be monitored for moisture. A group of filled and sealed vaults will be covered with an engineered cap consisting of layers of drainage materials and impervious materials. Topsoil and vegetation will be placed to cover the cap.

Illinois (Central Midwest Compact Region)

Illinois has not selected a site but has adopted certain design features for any new facility. Illinois has approximately 30 inches of precipitation per year and a shallow groundwater level. The technology proposed is an abovegrade concrete vault covered by an engineered soil cap and a high-density polyethylene layer (HDPE). The waste will be placed in either cylindrical or rectangular concrete overpacks and filled with grout material. In the Illinois facility, the overpacks will be placed into the vaults horizontally with a forklift. Once the vault is full, a concrete end wall will be poured.

The engineered soils cap and the HDPE layer will be placed over the concrete vault to protect the waste from water infiltration. The soil cap, which consists of layered drainage materials and impervious clay, will be topped with soil and vegetation.

Post-closure Plans

The Nuclear Regulatory Commission regulates licensing and closure of LLW disposal facilities. These requirements are listed in Title 10 of the Code of Federal Regulations Parts 61 and 20. In general, most states have incorporated the NRC regulations almost verbatim into their own regulations with very few differences regarding closure or post-closure requirements (National Low-Level Waste Management Program, 1992). NRC regulations state that disposal facilities must be sited, designed, operated, closed, and controlled after closure to assure that the exposures are within the limits established by the following four objectives (Subpart C, 10 CFR 61.40 through 61.44):

- Protection of the general population from releases of radioactivity. Releases of radioactivity from the site into water, air, soil or through plants or animals must not result in an annual dose to any member of the public >25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to the general environment. These release limits apply at the site boundary (NRC, 1989).

- Protection of individuals from inadvertent intrusion. Design, operation, and closure of the facility must ensure protection of any individual who inadvertently enters or occupies the site or who comes in contact with the waste after the institutional control period ends.

- Protection of individuals during operation. Operations at the land disposal facility must comply with the radiation protection standards of 10 CFR 20, except for releases of radioactivity from the site which are governed by 10 CFR 61. Every reasonable effort must be made to keep exposures during operation as low as reasonably achievable.

- Stability of the disposal site after closure. The facility must be sited, designed, used, operated, and closed to achieve long-term stability and to eliminate the need for ongoing active maintenance of the site following closure.

The Environmental Protection Agency regulates the disposal of hazardous wastes and closure of hazardous waste landfills; regulatory requirements are discussed in 40 CFR 264. If the waste is both radioactive and hazardous it is considered mixed waste. Any LLW facility that handles mixed waste will have to comply with both NRC/Agreement State regulations and EPA regulations.

NRC and agreement state regulations require disposal facility closure plans throughout the life cycle of such facilities. Plans for closure and institutional control of the facility must be submitted as part of the license application and a more comprehensive plan is required prior to actual closure. The closure plans submitted with the license application are preliminary because any site would be closed in accordance with the requirements and preferences of regulatory officials in place at the time of closure, some 20 or more years in the future. Preliminary closure plans are important, however, because they provide a basis for establishing a target amount of funds needed to close the facility and provide a basis for considerations for monitoring and maintenance during the institutional control period. These preliminary plans are required to be updated periodically, becoming more comprehensive in scope as the facility nears the end of its operational life.

Closure of a LLW disposal facility transforms a disposal site from operational status to inactive status. To be cost effective after closure, the facility should require only minimal maintenance. To ensure minimal maintenance, developers, operators, and regulators should consider closure during all phases of the design and operation of a LLW disposal facility (National Low-Level Waste Management Program, 1992). The Illinois Department of Nuclear Safety (1987) noted that mistakes made in design, construction, and operation may be costly to correct.

During siting, agencies should ensure detailed site characterization data are incorporated into the facility's design. This is because data deficiencies may result in errors or oversight during design, construction, and operation, possibly causing extensive and costly closure and stabilization activities.

During design and construction, developers should ensure that the objectives of the facility closure are incorporated such as: compliance with standards and specifications; inclusion of performance and environmental monitoring equipment; and the possibility of remedial action. Further during this phase, developers and regulators should consider financial assurance programs and whether they include provisions for investment and management of funds, duration of facility operation, closure, post-closure, and institutional control; the facility's disposal capacity; and the ability to adjust disposal fees. These fees are generally assessed during the operation of the facility.

During operation and disposal unit closure activities, operators should consider sequential closure of disposal units to promote the integrity of the engineered confinement structures, minimize water infiltration, and provide performance monitoring data which can be applied to subsequent disposal unit closures and final site closure. Operators should ensure disposal operations do not cause damage to closed units. Operators should also put in place provisions for the installation of additional monitoring equipment that may be required as each unit is closed. Finally, operators and regulators should ensure that comprehensive documentation of the waste inventory exists so that environmental monitoring results an be accurately interpreted and to expedite any needed remedial activities. The absence of complete documentation may introduce significant uncertainties regarding potential long-term environmental risks and may dictate a more cautious and conservative approach to site closure and post-closure activities (NRC, 1982).

During final site closure and stabilization, operators should ensure closure activities do not damage closed disposal units. Operators should also evaluate performance and environmental monitoring data to determine if any additional stabilization and closure measures are required. Additionally, all activities and monitoring data must be documented to provide evidence that closure is in conformance with the site closure plan.

During post-closure observation and maintenance, licensees should continue to document and evaluate performance and environmental data to provide assurance that the requirements for site closure are met.

Closed Facilities

Sheffield Illinois

The 1988 Agreed Order between US Ecology and the Illinois Department of Nuclear Safety specifies what the site operator must do to safely close the site and assure its continuing safety into the future. The closure plan requires the operator to:

- Construct a new low-permeability (less than 10^{-7} cm/s) clay cap over all the trenches. Cap construction began and was completed in 1989.
- Purchase a 170+ acre buffer zone around the site.
- Monitor and maintain the site and buffer zone until June 1998, when responsibility will transfer to the state. To compensate the state for its future obligations at the site, the operator must pay $2.5 million in quarterly installments of $62,500.00 over a ten-year period (1988–1998). These moneys, plus accrued interest, remain on deposit in a special fund of the state treasury reserved exclusively for Sheffield-related expenses.
- Take remedial action as needed to prevent discharge beyond the buffer zone of radioactive materials in excess of Illinois Department of Nuclear Safety limits. The operator has established financial assurance in the form of an irrevocable letter of credit

Data collected through 1994 indicate that the closure activities specified in the Agreed Order are functioning as designed. Levels of tritium in both ground and surface water are decreasing; residual contamination is mostly contained within the buffer zone and only minute quantities of radioactive material from the site are detected in ground and surface water beyond the buffer zone. Results of sampling and analysis have not detected any off-site exposures attributable to the Sheffield LLW facility. No known exposure to nearby residents has occurred (Illinois Department of Nuclear Safety, 1992).

Maxey Flats, Kentucky

One meter of soil was contoured over the disposal facility and contoured to promote drainage away from the trench. Since 1981, 11 hectares (28 acres) of the site surface have been covered with a polymer membrane to limit infiltration of surface water. Remedial actions are now being directed toward meeting Kentucky's regulatory requirement for longer-term stability by building a water repellent closure cap and putting in horizontal ground water flow barriers (Kirby, 1991).

Beatty Nevada

US Ecology submitted to the State of Nevada a proposed site stabilization and closure plan for the LLW facility that provides for post closure monitoring. The state reviewed and approved the plan and US Ecology began implementation in November 1993. As of early 1996, the site is in a post-closure and observation phase (CRCPD, 1996).

West Valley, New York

The New York State Department of Health has focused its efforts on minimizing water infiltration through an active maintenance program, establishing a monitoring program, and collecting site-specific data to allow for decisions to be made on eventual stabilization and closure. The strategy for closure will be developed as part of an ongoing effort to review the impacts of all waste management areas at the site.

Operating and Proposed Disposal Sites

Barnwell, South Carolina

Individual trenches are closed and capped with compacted on-site clay as they are filled. The topography of the site at closure was identified in the early 1980's and trench surfaces have been completed near those grades since that time. Due to migration of tritium in the groundwater from some of the early disposal trenches, enhanced caps are being installed on the early disposal trenches. The caps minimize infiltration into the trenches and reduce the water source driving the contaminants.

Site operators indicate that enhanced caps may not be necessary on the later disposal trenches because high integrity containers have been used for high concentration wastes since 1981, improved solidification media were required in 1983 and in 1983, the NRC required more detailed characterization and classification of waste and stability requirements for Class B and C waste materials. After the remaining closure activities are completed, the site will have gently sloping surfaces of native grass vegetation. Surface water runoff will be directed towards an on site retention pond. Maintenance of the site surface and environmental monitoring will continue through the institutional control period (Chem-Nuclear Systems, Inc., 1993).

Richland, Washington

Recommendations for the closure of the facility include addition of a multilayered cap that will provide a hydraulic barrier, a biotic barrier, a capillary barrier, and a soil and vegetation layer. The multilayered cap would be added over the current cap, which is not engineered. A closure plan for the site is under review. Closure is planned for 2065.

Proposed LLW sites

Preliminary closure plans were submitted in the Ward Valley, California, and Boyd County, Nebraska licenses. Preliminary closure plans are being developed for sites in Texas and North Carolina.

Cost and Duration of Site Characterization, Construction and Operation

Since 1980, the total expenditures to date to open new disposal facilities have been estimated at more than $500 million. These costs have been for site selection and characterization and the public involvement activities associated with siting. In most cases, the funds expended have come from assessments on large generators such as nuclear utilities. None of the costs to date have been used to construct new sites. Estimates for construction range from $30 million to as high as $70 million for each site.

The National Low-Level Waste Management Program plans to conduct detailed studies of operating costs for LLW disposal facilities in 1998. These studies are intended to assist those states in setting disposal rates for facilities operated as public utilities.

California selected a site for its facility in 1989 after two years of siting activities. In 1993, the California Department of Health Services issued a license to operate the facility. The site operator projects operation in mid-1999 pending a successful land transfer in 1998. Texas began site selection in 1983. The Texas Natural Resource Conservation Commission issued a draft license in 1996 and began administrative hearings on the license. The Commission projects operation in late 1999. Nebraska began siting in 1988. The site operator submitted a license application in 1990. The license is still under review. Projected operation for this facility is late 1999.

Related R&D Activities

Research and development for disposal of commercial LLW is limited. A recent study by the National Low-level Waste Management Program suggests that generators view the most important factor in making decisions about treatment and disposal is cost and not the need for new technologies. Generators want to manage waste using the least expensive method. Compounding the problem is the reticence of most generators and disposal site operators to take a risk by using unproven technology.

However, one hopeful technology for the disposal of LLW at Federal facilities is the use of fiber bags for some waste. While commercially, soil bags have been used for years for low-activity radioactive waste and naturally occurring radioactive waste, the Idaho National Engineering and Environmental Laboratory has historically packaged and disposed LLW in rigid containers such as wood and metal boxes. The INEEL is currently implementing soft-sided container use for the disposal of contact-handled LLW. The soft-sided containers are made of a woven polypropylene with high-density polyethylene liners and nylon lifting straps. The containers have a waste capacity of approximately 260 cubic feet and a weight rating of 20,000 lb. The containers can be vertically lifted (via a spreader bar and crane), enabling careful placement into a disposal facility waste stack. Compared to existing rigid disposal containers, soft-sided containers are more volumetrically efficient, more cost effective, and easier to use. In addition, soft-sided containers significantly reduce subsidence problems in LLW trenches.

Two companies have either developed or are researching new waste forms. These waste forms are not accepted by the disposal sites and thus require repackaging. One treatment method results in a metal ingot that now requires packaging in another container. Another treatment method under development is an effort to accelerate the aging of concrete already within a drum, resulting in a new waste form.

In the past, new waste forms were evaluated by the Nuclear Regulatory Commission. However, in 1996, the U. S. Nuclear Regulatory Commission formally announced that it would no longer accept topical reports on low-level radioactive waste forms for review and acceptance. This action left a void for commercial low-level radioactive waste treatment vendors. There was no longer a method to receive official validation that any new waste forms and containers met the stability requirements for disposal under the current regulations (Title 10 of the Code of Federal Regulations Part 61). The Nuclear Regulatory Commission's topical report review process was the only mechanism accepted by all of the agreement state agencies by which commercial waste treatment vendors could show that their waste forms met the stability requirements of the regulations.

At the urging of the American Society of Mechanical Engineers Radwaste Committee, the National Low-Level Waste Management Program began developing a new process soon after the Nuclear Regulatory Commission's announcement. Commercial waste treatment vendors were also interested in making the new process more cost-effective and less time-consuming than the NRC topical report review process, which was open-ended in terms of both cost and schedule. Because of this, the National Program adopted a requirement that the new process must be reasonable in cost and schedule. Vendors deserve a process that they can count on in their planning and budgeting. The testing protocols and draft process are undergoing peer-review.

Status of LLW Disposal in the United States

A national disposal system for commercial LLW does not exist in the United States. The laws passed in 1980 and amended in 1985 were not intended to develop a national system but rather to ensure equity for disposal. Clearly, the United States does not need 50 disposal sites, one for each state. The 1980 Act encouraged states to join together to form compacts with a designated state to host a disposal facility. Currently, Congress has approved nine compacts and a tenth compact is pending congressional approval. Some states have chosen not to join a compact and pursue siting on their own. Others have no intention of developing a new site.

As of October 1997, generators in all states except North Carolina have access to disposal. States in the Northwest and Rocky Mountain regions have formed compacts to restrict the import of wastes to their disposal site at Richland Washington to only those generators in their states. All other generators in the country with the exception of North Carolina can dispose at Barnwell, South Carolina. Envirocare of Utah is a facility that accepts contaminated soils and some Class A waste. Because Class A waste is the largest volume of low-level radioactive waste, many generators ship to the Envirocare facility if they meet the waste acceptance criteria because disposal is less expensive. While the Richland, Washington site is expected to operate for many more years, it is possible that the Barnwell site may close if the site operator cannot provide enough tax revenue to the state. If this were to happen, generators outside of the Rocky Mountain and Northwest states would have to store waste until a new site opened.

Unfortunately, proposed sites in California, Texas, North Carolina, and Nebraska will not satisfy all states needs because these facilities will not accept waste from generators outside their compact. In addition, the proposed sites are not expected to open soon. The Ward Valley site in California has a license but is situated on Federal land that the Department of Interior does not want to transfer to the state. Discussions over the conditions for a land transfer are at an impasse. The Sierra Blanca site in Texas is undergoing hearings on its preliminary license. The Nebraska Department of Health expects to issue an intent to license the site in Boyd County. However, the governor of the state has been opposed to the site since its inception and recently held a summit to examine whether the state should move ahead with its siting efforts. In North Carolina, the proposed site has suffered technical problems and is under examination. Pennsylvania, Connecticut and New Jersey continue to pursue finding a volunteer community for a disposal facility. However, no township has formally indicated an interest in siting a new facility and it will be years before a site could be found in these areas.

Some states have stopped pursuing new disposal facilities largely due to economic reasons. In mid-1997, the Midwest Compact voted to halt siting a facility in Ohio. Generators that are required to pay for the development of the new site through assessments proposed that projected low volumes would not make the site economically viable. Following a study of projected volumes and proposed disposal fees; generators in Illinois asked the Central Midwest Compact to halt siting until nuclear utilities begin decommissioning. Similarly, in Massachusetts, generators anticipated high disposal fees and further assessments and asked the state to halt siting.

Conclusion

Low-level radioactive waste disposal standards and techniques in the United States have evolved significantly since the early 1960's. Experience has resulted in stricter standards for the design, operation, closure and types of waste placed in LLW disposal facilities. These new standards and mitigating efforts at closed facilities have helped to ensure that the public has been safely protected from LLW.

Yet, with these stricter standards and greater level of protection for the public, states have been unable to open new disposal sites since they began the process in 1980. In most cases, the difficulty in opening new sites has not been due to technical difficulties, but rather political and public opposition that have contributed to lengthy siting processes and in many cases, litigation. Recently, generators have expressed concerns that new sites may never open and they are contesting assessments for siting new facilities. In addition, decreasing volumes and projected high disposal costs for new facilities have caused many state agencies to examine their approach to management of LLW.

References

Chem-Nuclear Systems, Inc., 1993. Interim Site Stabilization and Closure Plan for the Barnwell Low-level Radioactive Waste Disposal Facility, September.

Conference of Radiation Control Program Directors, Inc., 1996. Environmental Monitoring Report for Commercial Low-Level Radioactive Waste Disposal Sites. DOE/LLW-241. National Low-Level Waste Management Program, November.

Illinois Department of Nuclear Safety, 1987. Closing a Low-Level Radioactive Waste Disposal Facility, Unpublished research report. November.

Illinois Department of Nuclear Safety, 1992. Sheffield Low-level Radioactive Waste Disposal Site: A Brief Synopsis, December 12.

Kirby, LJ., 1991. Radionuclide Distributions and Migration Mechanisms at Shallow Land Burial Sites. US Nuclear Regulatory Commission NUREG/CR-4670, PNL-7582, prepared by Pacific Northwest Laboratory, Richland, Washington.

Murray, R. 1994. Understanding Radioactive Waste. Fourth Edition. Battelle Press, Columbia.

National Low-Level Waste Management Program, 1992. Considerations for Closure of Low-Level Radioactive Waste Engineered Disposal Facilities. DOE/LLW-133. January.

National Low-Level Waste Management Program, 1997. A Comparison and Cross-Reference of Commercial Low-Level Radioactive Waste Acceptance Criteria. DOE/LLW-239. April.

National Low-Level Waste Management Program, 1997. Comparative Approaches to Characterizing Low-Level Radioactive Waste Disposal Sites. DOE/LLW-199C.

Nuclear Engineering Company, Inc., 1979, Environmental Report for the Sheffield Low-Level Radioactive Waste Disposal Facility Near Sheffield, Illinois.

NUREG/CP-0028, 1982-3. Proceedings of the Symposium on Low-Level Waste Disposal, Vols.1-3.

Prudic, D., & Dennehy, K., 1987. Induced Changes in Hydrology at Low-Level Radioactive-Waste Repository Sites, in Proceedings for Safe Disposal of Radionuclides in Low-Level Radioactive Waste Repository Sites. U.S. Geological Survey, July 11-16.

U.S. Department of Energy, 1996. Integrated Data Base Report-1995: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics. DOE/RW-0006, Rev.12. Oak Ridge National Laboratory. December.

U.S. Nuclear Regulatory Commission, 1982, Environmental Assessment for the Barnwell Low-Level Waste Disposal Facility, NUREG-0879, January.

U.S. Nuclear Regulatory Commission, 1989. Regulating the Disposal of Low-Level Radioactive Waste, A guide to the NRC's 10 CFR Part 61, NUREG/BR-0120, August.