CONCRETE DISPOSAL VAULTS - AN ALTERNATIVE TO HAZARDOUS WASTE/MIXED WASTE EARTHEN LANDFILLS

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ABSTRACT

The Hazardous Waste/Mixed Waste (HW/MW) Disposal Facility is a new facility planned for on site processing and disposal of existing and future solid hazardous and/or mixed wastes generated at Savannah River Site (SRS). The first phase of the project is the completion of engineered above grade concrete disposal vaults which are to be permitted as hazardous waste disposal facilities and designed in accordance with the Resource Conservation and Recovery Act (RCRA) and appropriate U. S. Department of Energy (DOE) Orders.

The RCRA minimum performance standards promulgated in 40 CFR 264 and 265 are based on double lined earthen landfills. The regulations allow for alternative design and operational practices provided that the alternative design and operating practices, together with location characteristics, will prevent the migration of any hazardous constituents into the groundwater or surface water at least as effectively as the specified double lined earthen system. The engineered concrete vault structure for SRS is designed to comply and/or exceed the performance standards of the RCRA regulations and the associated RCRA technical guidance documents issued by the U. S. Environmental Protection Agency (EPA).

INTRODUCTION

The Savannah River Site (SRS) near Aiken, South Carolina, is a major installation of the U. S. Department of Energy (DOE). Operations at the site generate a variety of hazardous, low-level radioactive, and mixed wastes. Several locations at the site have been permitted for the disposal or storage of these wastes. One of the new facilities planned to handle existing and future wastes is the Hazardous Waste/Mixed Waste (HW/MW) Disposal Facility.

REGULATORY BACKGROUND

RCRA Performance Requirements for Liner Systems

Minimum technological requirements for hazardous waste landfill design and construction were introduced by Congress in the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA. In HSWA Section 3004(o)(1)(A), Congress required all new landfills to have double liners and leachate collection and removal systems above and between the liners.

Mixed waste must also be managed according to federal hazardous waste regulations under RCRA or the authorized state's equivalent regulations. Since South Carolina has been authorized to implement RCRA, the South Carolina Hazardous Waste Management Regulations, as administered by South Carolina Department of Health and Environmental Control (SCDHEC), apply. Relevant criteria appear in Section R.61-79.264 Subpart N (Landfills) of these regulations and are outlined below.

Under R.61-79.264.301 of Subpart N, a new hazardous waste (HW) landfill must meet the following major requirements:

- Landfill must contain two or more liners and a leachate collection system above and between the liners
- Top liner must be designed, operated, and constructed to prevent the migration of any constituent into such liner during operation and post-closure period of the facility
- Lower liner must be designed, operated, and constructed to prevent the migration of any constituent through the liner during operation and post-closure care of the facility. A 3 foot thick layer of recompacted clay or other natural material with a permeability of no more than 1×10^{-7} centimeter per second satisfies this requirement
- Liner material must withstand pressure gradients, chemical attack, climatic conditions, installation stresses, daily operational stresses
- Liner must be placed on a stable foundation
- Liner must cover all surroundings likely to be in contact with the wastes
- Primary leachate collection and removal system must ensure maximum leachate depth of 12 inches
- Leachate collection and removal systems must be chemically resistant to the wastes and leachates
- Leachate collection and removal systems must have sufficient strength and thickness to prevent collapse under bearing loads
- Leachate collection and removal systems must function without clogging through the scheduled closure of the landfill.

Section 264.301 also states that an alternative design and operational practice may be approved by SCDHEC if the owner/operator demonstrates that the alternative design and operating practices, together with location characteristics, will prevent the migration of any hazardous constituents into the groundwater or surface water at least as effectively as the specified (double liner, leachate collection) system. However, "prevent the migration" is not specifically defined and may be open to interpretation. A monitoring system may be required to demonstrate that the landfill prevents the migration of hazardous constituents into groundwater.

USEPA Design Guidance

In response to Congressional mandates, USEPA has issued various guidance documents on the design of liner systems and construction quality assurance programs. The USEPA clarifies its regulations through the issuance of guidance documents. Guidance documents are issued primarily to elaborate and provide direction on the implementation of regulations (USEPA, January 1986). The RCRA technical guidance documents present design, construction, and operating specifications that generally comply with the requirements of RCRA. The technical guidance documents do not supersede the RCRA regulations: they are issued to help interpret the requirements of the regulations. Officials at the USEPA and SCDHEC expect operators of HW facilities to meet the design parameters specified in the technical guidance documents. If design exceptions are taken, they must be technically well justified.

Liners

The USEPA "Draft Minimum Technology Guidance on Double Liner Systems For Landfills and Surface Impoundments" issued in May of 1985 discusses three types of liners: flexible membrane liners (FMLs); compacted clay liners; and composite liner systems which are comprised of an FML underlain directly with a compacted low permeability soil. The following are the key design features offered by the USEPA in the design of liners for landfills:

- Minimum thickness for an FML top liner is 30 mils. If the liner is not covered with soil within 3 months, a minimum of 45 mils is specified. The upper (FML) component of a composite bottom liner should be at least 30 mils thick
- FMLs should be protected from damage from above and below the membrane by a minimum of 10 inches of bedding material which is no coarser than the Unified Soil Classification System (USCS) sand (SP). Unless it is known that the FML material is not physically impaired by the material under load, 100 percent of the washed, rounded sand must pass the 1/4 inch sieve. A synthetic drainage layer may be able to function as appropriate bedding if brittle failure under the design loads can be ruled out
- The liner should be chemically resistant to the leachate generated in the unit using the results of USEPA Test Method 9090 or an agency approved equivalent test method.

Leachate Collection and Removal Systems (LCRS)

The LCRS is comprised of drainage layers, filters, cushions, sumps and pipes, and appurtenances. The drainage layer may consist of a synthetic material called a "net" which is usually less than 1 inch thick and has similar design liquids capacity to that of granular materials. The primary selection criteria for this layer is high hydraulic transmissivity, low compressibility, and chemical compatibility with collected leachate. If the drainage layer is specified as granular, it is comprised of clean sand or gravel with a low percentage of fines. The main selection criteria for a granular layer are high hydraulic conductivity and low capillary tension.

The USEPA "Draft Minimum Technology Guidance on Double Liner Systems for Landfills and Surface Impoundments" offers the following key design features for LCRSs.

The purpose of the LCRS located above the top liner is to ensure that the leachate depth above the liner does not exceed 1 foot during the operation and post-closure care period. It should have:

- At least a 12 inch thick granular drainage layer that is chemically resistant to the waste and leachate, with a hydraulic conductivity not less than 1×10^{-2} cm/sec and a minimum bottom slope of 2 percent; or equivalent synthetic drainage nets
- A graded granular filter or synthetic filter above the drainage layer to prevent clogging
- A primary leachate collection system that covers both the bottom and sidewalls of the unit. (The applicability of this criterion is on a site by site basis.)
- A sump in each unit or cell capable of continuous functioning. The sump should contain a conveyance system for the removal of leachate from the unit such as either a sump pump and conveyance pipe or gravity drains.

The secondary LCRS, located between the two liners, should be designed to rapidly detect, collect, and remove all liquids between the two liners during the operation and post-closure period. Major design parameters include:

- Production of little or no hydraulic head on the bottom liner
- Minimum bottom slope of 2 percent and a minimum hydraulic conductivity of 1×10^{-2} cm/sec
- Sump located at least 12 inches below the drainage layer grade that is separate from the primary leachate collection system sump
- Chemical resistance to the leachate
- Designed and operated to function without clogging.

Leak Detection System Requirements

The following proposed leak detection system requirements apply to the secondary LCRS located between the two liners in a landfill:

- For synthetic materials, a minimum hydraulic transmissivity of 5×10^{-4} square meters per second
- For granular materials, a 1 foot thick drainage layer with a hydraulic conductivity of 1 cm/sec
- A minimum bottom slope of 2 percent, as recommended in the existing draft guidance for LCRSs
- The sump designed to detect a top liner leakage rate in the range of the Action Leakage Rate, which is in the order of 5 to 20 gal/acre/day, or a site specific rate may be established
- A site specific Rapid and Large Leakage Rate to be established which indicates a serious malfunctioning of the secondary LCRS, and compilation of a Response Action Plan to deal with excessive leakage.

DOE and NRC Requirements

Requirements for radioactive mixed waste appear in DOE Order No. 5480.2 (Hazardous and Radioactive Mixed Waste Management) and 6430.1A, (General Design Criteria) and Nuclear Regulatory Commission (NRC) regulations

under 10 CFR Part 61. These requirements appear to be essentially the same in objective and process, but the NRC regulations are more design oriented.

Based on SRS policy, mixed waste facilities will be designed, constructed, and operated under state and federal environmental regulations. The NRC does not have jurisdiction over the Savannah River Site DOE facility; however, the following summary is presented for reference purposes.

The NRC regulations pertain to the disposal of low-level radioactive waste in near surface facilities, within 30 meters of the earth's surface. The primary sections relevant to design criteria for a concrete vault are 10CFR61, Subpart C - Performance Objectives; and Subpart D - Technical Requirements for Land Disposal Facilities. Under Subpart C, there are two general areas relevant to design:

- Concentrations of radioactive material released to the environment through groundwater, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public
- Disposal facility must be sited, designed, used, operated, and closed to achieve long term stability of the disposal site and to minimize the need for ongoing active maintenance of the disposal site.

Under 10CFR61 Subpart D, the following are the major general concepts concerning technical design for a land disposal site, largely related to meeting the performance objectives under Subpart C:

- Long term isolation of the waste and avoidance of the need for continuing active maintenance after site closure
- Covers must be designed to minimize water infiltration, direct percolating or surface water away from the disposed waste, and resist degradation by surface geologic processes and biotic activity
- Disposal site must be designed to minimize the contact of standing water with waste during disposal, and contact of percolating or standing water with waste after disposal
- Wastes must be placed in a manner that maintains the package integrity during emplacement, minimizes the void spaces between packages, and permits the void spaces to be filled. Void spaces between waste packages must be filled with earth or other material to reduce further subsidence within the fill
- Alternative provisions for the segregation and disposal of wastes and design and operation of a land disposal facility may be authorized on a site specific basis if the performance objectives of Subpart C are met
- Institutional control of access to the site is required for up to 100 years.

The DOE orders and design criteria provide general guidelines for hazardous and mixed waste disposal facilities. The orders require the SRS to fully comply with all applicable state and federal regulations. In addition, DOE has entered into an agreement with USEPA, and SCDHEC to design, construct, and operate hazardous waste and mixed waste facilities in accordance with currently promulgated regulations.

EVALUATION OF EXISTING DESIGN

Performance Criteria for the HW/MW Disposal Vaults

The selection of a design for the vaults is based on regulatory requirements as well as on specific performance criteria established for the facility. The regulatory requirements for the HW/MW vaults have been presented. Performance criteria for the HW/MW disposal vaults outlined in the site specific Environmental Information Document (EID), Environmental Impact Statement (EIS), and the RCRA Part B Permit Application documents are summarized below.

Performance criteria have been identified in the EID to ensure that the long term objectives of the disposal site will be incorporated in the site selection and design as follows:

- Groundwater Quality - The concentration of chemical species and radionuclides in groundwater at the disposal site boundary must not exceed those established in the USEPA Interim National Primary Drinking Water Standards Regulations, 40CFR61 (1977)
- Minimum Depth Between Waste and Water Table - The minimum distance between the waste and the groundwater table will be at least 5 feet (1.5 meters)
- Surface Water and Erosion Control - Surface topography should be such as to minimize erosion (i.e., minimum slope), and surface waters should be routed so as to avoid erosion and infiltration
- Subsidence - Subsidence of wastes and backfilled soil should be minimized to avoid undue maintenance of surface topography and to avoid enhanced water infiltration and potential unacceptable migration of radionuclides
- Post-Closure Control - It is assumed for the purpose of projecting radionuclide movement that institutional control will be maintained for 100 years following site closure.

The EIS summarizes the Federal and State of South Carolina environmental requirements for waste management activities at SRS to protect groundwater, human health and the environment.

Design Summary of the HW/MW Disposal Vaults

The engineered disposal vaults are designed to isolate the solidified waste from the environment by relying on an engineered structure, lined with a primary and secondary containment and leachate collection system. Specific design details of the design are summarized in the following sections.

General Design Details

Each HW/MW vault is a reinforced concrete structure having the following nominal outside dimensions: 200' x 50' x 25' high. Each vault is divided into six identical waste cells with the following nominal inside dimensions: 32' x 44' x 18' high. The thickness of the walls varies from 18 inches (interior walls) to 30 inches (exterior walls). The concrete mat is 2 feet thick.

During the time that the vault is receiving waste, removable steel covers will be used to prevent the entry of rainwater

into the cells. Lifting lugs on the covers allow their removal to enable waste placement within the individual cells via an overhead gantry crane. Waste to be disposed in the HW/MW vaults will be packaged in concrete disposal containers (CDCs).

The CDCs will be stacked four high, each weighing a maximum of 8100 lbs with nominal dimensions of 4' x 6' x 4' high. In certain instances, wastes packaged in 55 gallon drums will be stacked on pallets and also loaded into the vaults. After a vault has been filled, precast concrete tees will be placed across the width of the waste cell. A cast in place concrete cap will be constructed over each cell. The concrete cap will be covered with an Ethylene Propylene Diene Monomer (EPDM) roofing material to prevent the infiltration of precipitation. During final closure, the disposal vaults will be capped with a soil cover.

The foundation for the disposal vaults will be placed on firm, undisturbed soil, capable of supporting the anticipated loads of the disposal vault, waste, concrete cap, and final cover. The design load for bearing is approximately 4000 psf. The maximum allowable differential settlement is 1 inch. The base of the disposal vault will be a minimum of 5 feet above the seasonal high water table.

The leachate collection and leak detection systems will remain in service during the active life of the facility, including closure and post-closure care periods. The period of "institutional control" will be a minimum of 100 years.

Liner System Design and Construction

A double liner system with a double leachate collection system will be installed in each waste cell, as shown in Fig. 1. The design for the liners specifies that they are fabricated from high density polyethylene (HDPE) materials. The primary, or top, liner is 80 mils thick and the secondary, or bottom, liner is 60 mils thick.

The HDPE liners will be installed on the floor and side walls of each waste cell. Liner sections will be joined by a fusion welding technique. The liners will be secured to the walls near the top of the vault as well as at the floor corners, and special stainless steel and neoprene washers will be used to ensure a leak free seal. An HDPE cap will be placed over the anchor supports and welded in place. Rubber strips will be installed along the waste cell walls to protect the liner system from damage during placement of the waste containers.

Hydraulic pressure on the bottom liner will be maintained below the regulatory requirement of 1 foot by preventing the intrusion of rainfall, prohibiting the disposal of wastes containing free liquids, and monitoring/maintaining the leachate collection system.

Leachate Collection Systems

Each waste cell contains a leachate collection system above the top liner and a second separate leachate collection system between the top and bottom liners.

The leachate collection system located above the primary liner is a 12 inch sand layer. Any leachate generated within the waste cell will drain through this sand layer to a central drain located at the center of each cell. A layer of filter fabric supported by a drain cover will be installed over the leachate drain inlet to prevent the pipe from filling with sand. The drainpipe designed to drain leachate above the top liner is nested within the leak detection drain pipe. The drain pipes will be installed within the concrete foundation of the disposal vault and be sloped to drain any leachate to the outer wall. The drainpipes will terminate at collection sumps designed for pumping, as required.

The leachate collection system located between the two liners is composed of a drainage net, and monitors the performance of the top liner. It consists of an open grid structure. The hydraulic transmissivity is specified to be greater than 1×10^{-3} square meters/sec. It will be installed along the floor and the walls, and will drain from a central point within each waste cell to the sump.

One set of sumps (one for each leachate collection system) will be used to drain each cell within the vaults. Riser pipes will be installed from each sump and liquid indicators with alarms will be installed within each riser pipe. The removal notification will alarm before a liquid buildup of 1 foot occurs above the top liner.

Conformance to Regulations

The regulatory requirements outlined in the previous Section, Regulatory Background, are compared to the design parameters in Table I.

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BIBLIOGRAPHY

Application for a Hazardous Waste Part B Permit, Savannah River Site, U.S. DOE, Volume IX, Hazardous Waste/Mixed Waste Disposal Vaults, Revision 1, January, 1990

DOE, Environmental, Safety, and Health Program for Department of Energy Operations, Order 5480.1B, September 23, 1986

DOE, General Design Criteria Manual, Order 6430.1A, April 6, 1989

DOE, Hazardous and Radioactive Mixed Waste Management, Order 5480.2, December 13, 1982

DOE, Radiation Protection for Occupational Workers, Order 5480.11, Change 1, July 20, 1989

Environmental Impact Statement for Waste Management Activities for Groundwater Protection, Savannah River Plant (EIS), U.S. DOE DOE/EIS-0120, December 1987

Environmental Information Document, New Hazardous and Mixed Waste Storage/Disposal Facilities at the Savannah River Plant, DPST-85-953, E.I. DuPont de Nemours and Co., April 1987

Nuclear Regulatory Commission Regulations, 10 CFR Part 61

Resource Conservation and Recovery Act, 40 CFR parts 264 and 265

South Carolina Hazardous Waste Management Regulations, South Carolina Department of Health and Environmental Control, Amended June 23, 1989

Title I Design Summary for Hazardous Waste/Mixed Waste Disposal Facility, Line Item 89-D-175, Project S2944, Westinghouse Savannah River Company, September 1989

TABLE I

Evaluation of Existing Design

	Regulatory Design Parameters	Vault Design
	RCRA Minimum Performance Standards: (Promulgated in 40CFR264 and 265)	
1.	Top liner designed, operated and constructed to prevent migration of any constituent into such liner	The existing design for minimum technological requirements (MTR) calls for a double liner system consisting of a FML top liner
2.	Lower liner designed, operated, and constructed to prevent migration of any constituent through such liner	USEPA interprets lower liner requirements to mean the lower liner should be composed of 3 feet of compacted clay with a maximum saturated hydraulic conductivity of no more than 1×10^{-7} cm/sec (USEPA, August 1989). The bottom FML (with underlying concrete) satisfy the minimum performance standards as an alternative design equal to RCRA specified liner system.
3.	Liner material withstands chemical attack, climatic conditions, installation stresses, operation stresses, and pressure gradients	Based on Published Chemical Compatibility Matrices HDPE liners comply
4.	Liner placed on stable foundation	Differential settlement less than 1 inch
5.	Liner covers surroundings likely to be in contact with wastes	Walls and floor of vault are covered
6.	Primary Leachate Collection system ensures maximum leachate depth of 12 inches	Primary LCRS design, in conjunction with operating conditions specified by SCDHEC ensure maximum leachate depth of 12 inches. See Item (13)
7.	LCRSs are chemically resistant to wastes	Granular layer of sand/gravel is chemically resistant to wastes. Secondary LCRS of HDPE is chemically resistant to wastes.
8.	LCRSs have sufficient strength	Solid rib geonets are compatible with design loads
9.	LCRS functions through closure without clogging	No fines in leachate are anticipated due to the engineered barriers of encapsulation and containerized waste in CDCs. Additionally, sand/gravel layers should be clean and free of fines.
	USEPA Guidance Document Requirements (Issued to interpret the requirements of RCRA; design parameters do not supersede RCRA requirements)	
10.	Top liner *minimum* thickness of 30 mils/45 mils	Top liner has specified thickness of 80 mils
11.	FML protected by 10 inches bedding material, passing 1/4 inch sieve	12 inch sand layer specified
12.	Liner shown to be chemically resistant to leachate using USEPA 9090 test or equivalent	HPDE is chemically resistant
13.	Primary LCRS of 12 inch thick granular layer with hydraulic conductivity not less than 1×10^{-2} cm/sec; min 2% slope	Design meets requirements

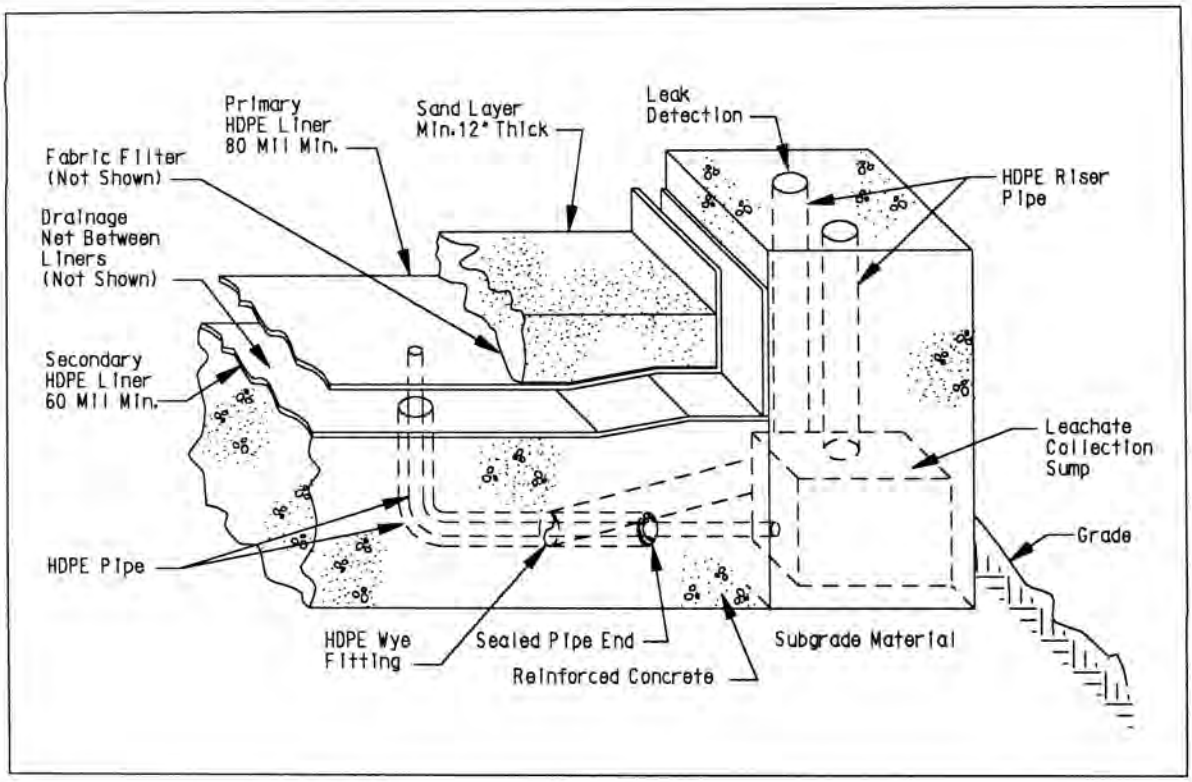

Fig. 1. Leachate detection/collection system.

USEPA, Draft Minimum Technology Guidance on Double Liner Systems for Landfills and Surface Impoundments - Design, Construction, and Operation, EPA/530-SW-85-014 Draft, Second Version, May 24, 1985

USEPA, Requirements for Hazardous Waste Landfill Design, Construction, and Closure, EPA/625/4-89/022, USEPA, Cincinnati, OH, August 1989

USEPA, Resistance of Flexible Membrane Liners to Chemicals and Wastes, PB86-119955, NTIS, Cincinnati, OH, October 1985

USEPA, Test Methods for Evaluating Solid Waste - Method 9090: Compatibility Test for Wastes and Membrane Liners, Lab Manual, Vol 1C, SW-846, September 1986