LOW-LEVEL WASTE DISPOSAL TECHNOLOGY: CLASSIFICATION AND COORDINATION

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ABSTRACT

The objective and brief history of the coordinating committee for LLW Disposal Technology are presented. The contributions of the Electric Power Research Institute to the classification of LLW disposal technologies are briefly discussed. Design bases used in developing generic conceptual designs are set forth and the generic conceptual designs for several disposal technologies are described. The limitations of existing performance codes as they relate to assessment of LLW disposal technologies are presented.

INTRODUCTION

The use of shallow land burial (SLB) for the disposal of low-level radioactive waste (LLW) has come under increased scrutiny. Only three of the six commercial LLW disposal sites remain open. The experience gained from the three closed sites and other commercial and government disposal sites has caused considerable interest in a wide range of disposal technologies in addition to SLB. The Electric Power Research Institute (EPRI) has recently initiated a project to develop an information package that will consistently classify all LLW disposal technologies, provide generic conceptual designs, and measures of performance and costs for them. This project is part of a broader Program directed toward the development and introduction of advanced chemical processing techniques for the control of radioactive materials using the following approaches:

1. Source minimization
2. LLW treatment
3. Volume reduction strategies
4. LLW solidification, containment, storage, and disposal

Some of the results of this program have been presented in previous Waste Management Symposia.[1-5]

The objectives of this specific project are to:

1. Define disposal technologies with a self-consistent methodology.
2. Define design features and develop generic conceptual designs.
3. Characterize performance with existing models and develop models for disposal technology performance comparison.
4. Prepare preliminary cost estimates.
5. Evaluate the economic and technical impacts on electric utilities generating LLW.

COORDINATING COMMITTEE FOR LLW DISPOSAL TECHNOLOGY

EPRI's early interest in alternative disposal technologies led to its participation in the formation of the Coordinating Committee for LLW Disposal Technology.

The Committee was formed in May 1985 for the coordination of LLW disposal technologies research and development. The institutional participants in the Coordinating Committee for LLW Disposal Technology represent the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Nuclear Regulatory Commission, the Electric Power Research Institute, and the states of Illinois, New York, Pennsylvania, and Texas. The Southern States Energy Board serves as coordinator, and EG&G Idaho, Inc. and Rogers and Associates Engineering Corporation provide additional technical support.

The purpose of the Coordinating Committee is to bring together the various parties with research and development interests in determining viable options for the disposal of low-level radioactive wastes. This committee provides a framework for coordinating federal, state, and private sector activities in an effort to define and develop common benchmarks for evaluating disposal technologies. The coordinating committee offers a vehicle for reviewing individual work efforts and, to the extent practicable, maintains a shared focus on research and development activities. Independent research efforts are carried out in a complimentary manner, based upon consistent assumptions and definitions adopted by the committee.

The committee meets approximately quarterly at various locations throughout the country, depending on member's needs and related activities. For example, the organizing meeting was in Washington, D.C. The July meeting was in Chicago, the September meeting was in Las Vegas, the day before the DOE LLW Information Meeting and the December meeting was at EPRI offices in Palo Alto, California. The meeting agenda is informal, and usually consists of brief participant presentations on key parts of specific organization projects. Considerable discussion generally accompanies and follows the presentations. For example, one topic that was presented and discussed in some of the meetings was the EPRI waste classification system. The final version of the classification system benefited greatly from the discussions and feedback that occurred from committee members. In addition, the Coordinating Committee's meetings enabled the classification system to be molded into a useful tool that several organizations began using.

CLASSIFICATION SYSTEM

The classification system uses the following functional features to describe a disposal technology:

1. Relationship to Natural Grade (above/below).
2. Depth of Cover (none, shallow, deep).
3. Structure (no, yes, modular).
4. Fill (no, yes).

Descriptors have been associated with each functional feature, so that each particular combination of descriptors can be used as a generic name for the particular disposal technology. These generic names are listed in Table 1 for the 17 viable generic disposal technologies based on the four dominant functional features. Traditional names of several disposal technologies are also given in the table. Additional information about the classification system is presented elsewhere.[6] To date, the NRC, DOE, and several states and compacts have used the classification system in their work.

GENERIC CONCEPTUAL DESIGNS

In engineering design efforts, a major initial step is developing the design basis, which is the definition of the constraints and conditions within and under which the system being designed must operate. There are many elements of the design basis that are common to all disposal technologies and several that are unique to individual disposal technologies.

Philosophy of Disposal

In all disposal technologies, it has been assumed that the terms, requirements, and philosophy of 10CFR61 apply.

Occupational exposure limits prescribed by 10CFR20 were used as a guideline for design, though these requirements were not explicitly evaluated in the design process. For this project, it has been assumed that all waste is placed in the disposal unit by a crane which is located adjacent to, not in, the disposal unit.

Concrete Structures

A basic tenent of the design process was that the existence of structure capability provided by the disposal facility was sufficient to satisfy the NRC's requirement for stable waste form regardless of the class waste. Furthermore, the presence of structural capability was also assumed to satisfy the requirement to provide intruder protection from Class C waste for 500 years. In the absence of quantitative and explicit design guides upon which to base a design for such life expectancy, conservative assumptions were made in the design process which provide some expectation of long life. In performance assessment which will follow, the assumption will be made simply that the structure remains intact for 500 years.

Where concrete is used in the design of any disposal technology, care must be taken that the potential for soil-concrete chemical reactions is minimized. In locations where the soil contains high levels of sulfates, Type V Portland cement is required to accomplish this objective. An additional feature of the concrete structure design that also impacts the hydraulic behavior of the disposal technology is the presence of a waterproof membrane on all exterior surfaces located below natural grade.

Site Capacity

The capacity of all facilities considered in this conceptual design effort was assumed to be 250,000 m^3 of waste at the time of disposal. For many LLW waste streams, there is considerable volume change if the waste is processed prior to disposal. The reference size is about 8 percent of the LLW expected to be generated in the United States over the next 20 years. Thus, about 12 such facilities would be required over this time span to accommodate total U.S. production.

Overall Dimensions of Disposal Units

The overall dimensions of disposal units are similar to those of currently used trench designs. The length of the typical disposal unit is generally 200 meters, the width is generally about 30 meters, and the waste depth is about 7 meters. All of these dimensions cannot be satisfied for all disposal technologies because of structural limitations or operational considerations.

TABLE I

GENERIC DEFINITION OF DISPOSAL TECHNOLOGIES

	Structure	Above/Below Grade	Cover	Fill	Generic Name	Traditional Name
1	N	A	S	Y	Covered Placement With Fill	EMCB Tumulus
2	N	B	S	Y	Buried Placement With Fill	Shallow Land Disposal
3	N	B	D	Y	Deep Placement With Fill	Deep Land Disposal Unlined Auger Hole
4	Y	A	N	N	Uncovered Structure Without Fill	Above Ground Vault
5	Y	A	N	Y	Uncovered Structure With Fill	
6	Y	A	S	N	Covered Structure Without Fill	
7	Y	A	S	Y	Covered Structure With Fill	
8	Y	B	S	N	Buried Structure Without Fill	Below Ground Vault Concrete Lined Trench
9	Y	B	S	Y	Buried Structure With Fill	EMCB Monolith
10	Y	B	D	N	Deep Structure Without Fill	Mined Cavity
11	Y	B	D	Y	Deep Structure With Fill	Lined Auger Hole
12	M	A	S	N	Covered Modules Without Fill	
13	M	A	S	Y	Covered Modules with Fill	
14	M	B	S	N	Buried Modules Without Fill	
15	M	B	S	Y	Buried Modules With Fill	Modular Concrete Canister Disposal
16	M	B	D	N	Deep Modules Without Fill	
17	M	B	D	Y	Deep Modules With Fill	

Segregation of Waste by Waste Class

For two of the disposal technologies, Class A waste is assumed to be segregated from Class B and Class C wastes. These two are Buried Placement with Fill and Covered Modules with Fill Colocated with Buried Structure with Fill. In the first case, the segregation is essentially forced by the requirements of 10CFR61, since there was assumed to be no stable waste form for Class A waste, and since the disposal technology provided no structure to satisfy the stability criterion of the regulation. For Covered Modules with Fill Colocated with Buried Structure with Fill the split was retained in order to reproduce the French system as closely as possible.

For the other four disposal technolgies, Buried Structure with Fill, Uncovered Structure with Fill, Buried Modules with Fill, and Deep Structure with Fill, the physical stability requirement of 10CFR61 was assumed to be satisfied by the structure provided at the disposal facility. Thus, the potential for water infiltration because of subsidence was assumed to be minimized by the structure provided as an integral part of the disposal technology. Therefore, the need to segregate Class A waste from Class B and Class C wastes is effectively mitigated by the structure provided by the disposal technology.

Only in the case of Buried Placement with Fill was it considered necessary to segregate Class B from Class C wastes. For other than this one exception, it was justified by the assumption that the disposal of both classes of waste would include the provision of the intruder protection required for the disposal of Class C waste. In the cases where structure is provided by the disposal technology (Buried Structure with Fill, Uncovered Structure with Fill, Buried Modules with Fill, and Covered Modules with Fill Colocated with Buried Structure with Fill), the structure was assumed to satisfy the intruder protection requirement. For Buried Placement with Fill the intruder protection is provided by 5 m of earthen cover.

In all disposal technologies, it has been assumed that waste is either in a stable form, as required for Class B and C wastes, or that the waste containers are backfilled with some material which aids in minimizing subsidence, as required for Class A waste. For Class A waste, the material is assumed to be sand, which does not have significant structural capability.

Support Facilities

A generic site layout is shown in Fig. 1. The layout assumed in the conceptual designs makes no allowances for peculiarities which will undoubtedly reduce that extent of usable land at any real site.

Common support facilites were provided for all disposal technologies. These included such components as the administrative building, health physics/security building, warehouse for construction materials, waste storage building, equipment storage/maintenance building, holding and evaporation ponds, and truck washdown facility. In some cases a larger warehouse must be provided because of larger quantities of material that are consumed in the operating phase.

Normally waste received at the disposal facility will be disposed of immediately. However, there may be circumstances in which the waste cannot be immediately disposed, e.g., inclement weather or labor strife. Therefore, a waste storage facility was provided, based on the possibility that waste may not be disposed of during bad weather. The waste storage facility was sized to accommodate deliveries of waste for two bad-weather months. In practice, this occurs during the winter when nuclear power plants, which produce about 90 percent of all LLW are generally on-line to the maximum possible extent. Since much of the LLW from power plants is generated during outages, a lull in deliveries can be expected during winter months. However, for this project, the delivery rate upon which the capacity of the waste storage facility is based was taken to be that more representative of the maximum LLW generation rate.

Evaporation ponds were sized to accommodate the rain intercepted by the open disposal unit for the worst precepitation month on record among the three sites being considered for the project (Southeast, Northeast, and Southwest). Thus, these ponds were sized based on the precipatation at the Southeast site where the worst precipitation month on record produced 11 inches of rain. Each disposal unit is provided with a French drain system and an active pumping system which is assumed to be available during operations, and the closure and institutional care periods.

If there is no potential that the water is contaminated, the water is discharged offsite without delay.

Buffer Zone

For all disposal technologies a buffer zone of 100 meters was provided between unrestricted land areas and any area where radioactive material could be handled or could exist. Access to the area within the buffer zone where radiation exposures could occur is controlled to limit exposures to badged personnel only. In all conceptual designs, administrative facilities and functions exist or are conducted outside the inner perimeter but within the buffer zone which is defined by the outer perimeter.

Generic conceptual designs for four of the disposal technologies are discussed later in this paper.

BURIED PLACEMENT WITH FILL

The waste in each disposal unit is covered with a 2 meter cover system consisting of 50 cm topsoil on 40 cm gravel, 10 cm asphalt, 20 cm gravel, and 80 cm clay. Although the cover systems currently used in actual disposal operations are much simpler, the Alternative Disposal Unit Cover System offers several advantages and has been assumed in all cases where a cover of 2 meters thickness is required.

The Class A and B trenches are 200 meters in length and 40 meters wide. Class A trenches are 9 meters deep while the Class B and C combined trench is 12 meters deep. The efficiency of waste placement within a Class A or Class B/C trench for Buried Placement with Fill Land Disposal was conservatively estimated to be about 80 percent. Thus, 5 trenches are required to dispose of 208,200 m^3 of Class A waste and 1 trench to dispose of 40,230 m^3 of Class B and C waste. There is a 30 meter buffer between Class A and Class B/C trenches. The trenches of a given waste class are separated by 10 meters of earth that permits vehicles to be maneuvered for disposal and support activities.

Considering the earth walls that separate trenches, the overall efficiency of placement for Class A and B waste is about 34 percent. This latter efficiency leads to a disposal area of 20 acres (8 hectares) for the disposal of 250,000 m^3 as disposed, and, allowing for a buffer zone of 100 meters, a total site area of about 85 acres. Thus the total disposal area for Buried Placement with Fill Disposal is 37 acres (15 hectares).

BURIED STRUCTURE WITH FILL

For disposal of LLW in Buried Structures with Fill the overall dimensions of the trenches within which the disposal structures are constructed are similar to those for Buried Placement with Fill.

The total length of a major disposal unit is 133 m, the width is 31 m, and the height is 10 m. As shown in Fig. 2, each unit contains 39 cells of interior dimension 10 m by 10 m. The volume of one cell is about 825 m^3, so that three cells are filled every two months, and a disposal unit is filled and closed every 2 years.

The roof is 91 m thick and is provided with a small camber and slope for drainage. The foundation slab is also 91 cm thick. All wall, floor, and roof thicknesses were sized considering maximum operations loads and seismic loads, with safety factors selected conservatively to accommodate degradation.

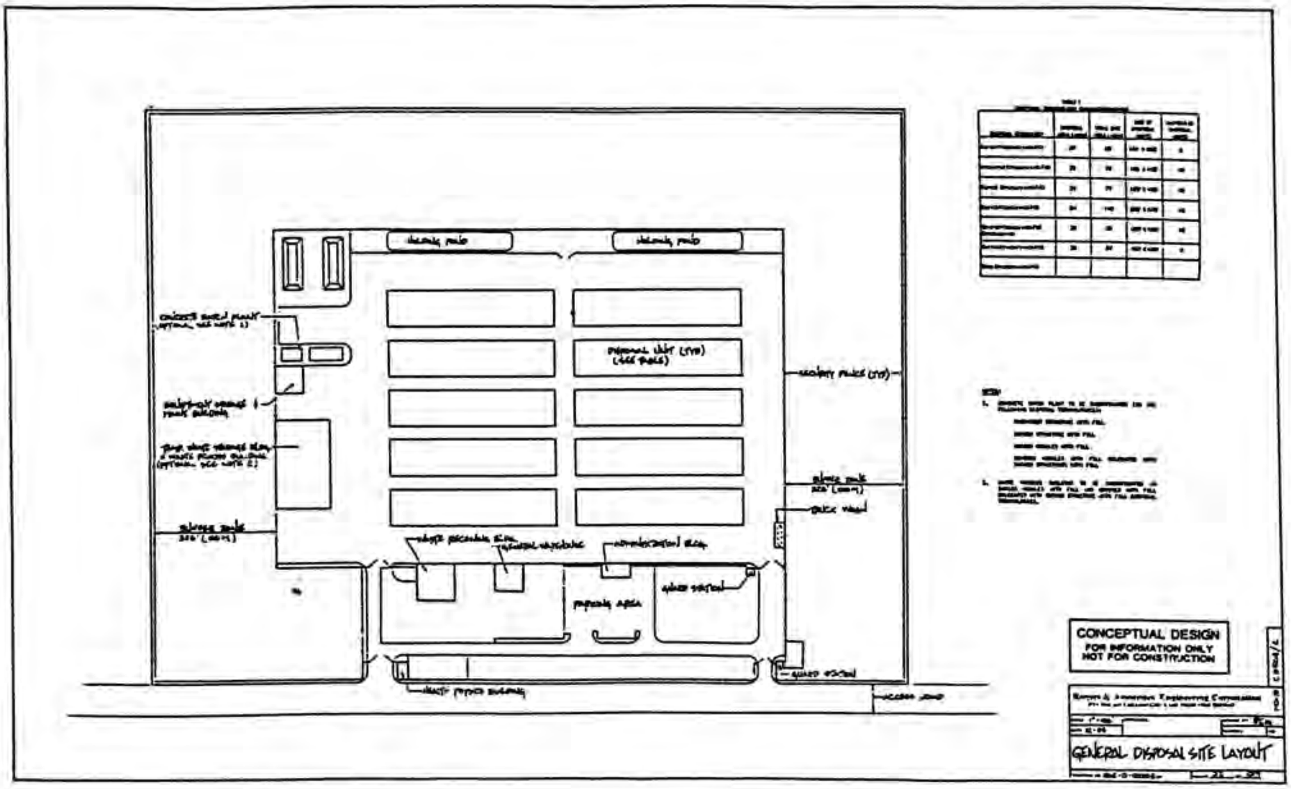

Fig. 1. Generic Site Layout

Because the cells provide structural capability that is considered sufficient for stability and intruder protection needs, it has been assumed that Class A waste is disposed in the same facility with Class B and C waste. Thus there is no need to segregate received waste by waste class when using Buried Structures with Fill.

The design of the steel reinforced concrete walls is based on the conservative application of good engineering practice in the design of concrete structures. Although there are no design guides currently that allow concrete structures to be designed with a life expectancy of 500 years, the considerations suggested by others [7] have been taken into account in an effort to render a facility which is designed to withstand all disruptive and deleterious forces that may act upon the structure over such a time period.

UNCOVERED STRUCTURE WITH FILL

The design of Uncovered Structure with Fill is similar to that of Buried Structure with Fill except that the vaults are located above natural grade, rather than below. In addition, wall thicknesses are nearly the same in order to satisfy requirements for life expectancy against natural elements and intruder protection.

As with Buried Structure with Fill, there is no need to segregate the received waste by waste class because of the assumed adequacy of the structure to provide both physical stability and intruder protection.

Since the walls of the cells are assumed to be in place during the disposal process, placement is complicated because the crane operator is unable to observe the effects of his control actions. For this reason, an overhead crane was assumed to be utilized to allow the operator to directly observe the movements of the equipment and the load.

BURIED MODULES WITH FILL

In the Buried Module with Fill disposal method, all waste is disposed of inside concrete canister overpack containers. Each canister has an inside diameter of 183 cm, and a height of 183 cm. The minimum wall thickness is 15 cm and is steel reinforced concrete.

Concrete canisters can be placed 3 tiers high in the disposal trench with cranes or forklifts.

Because the canisters are assumed to satisfy all requirements for physical stability and intruder protection, there is no need for segregation of waste by waste class.

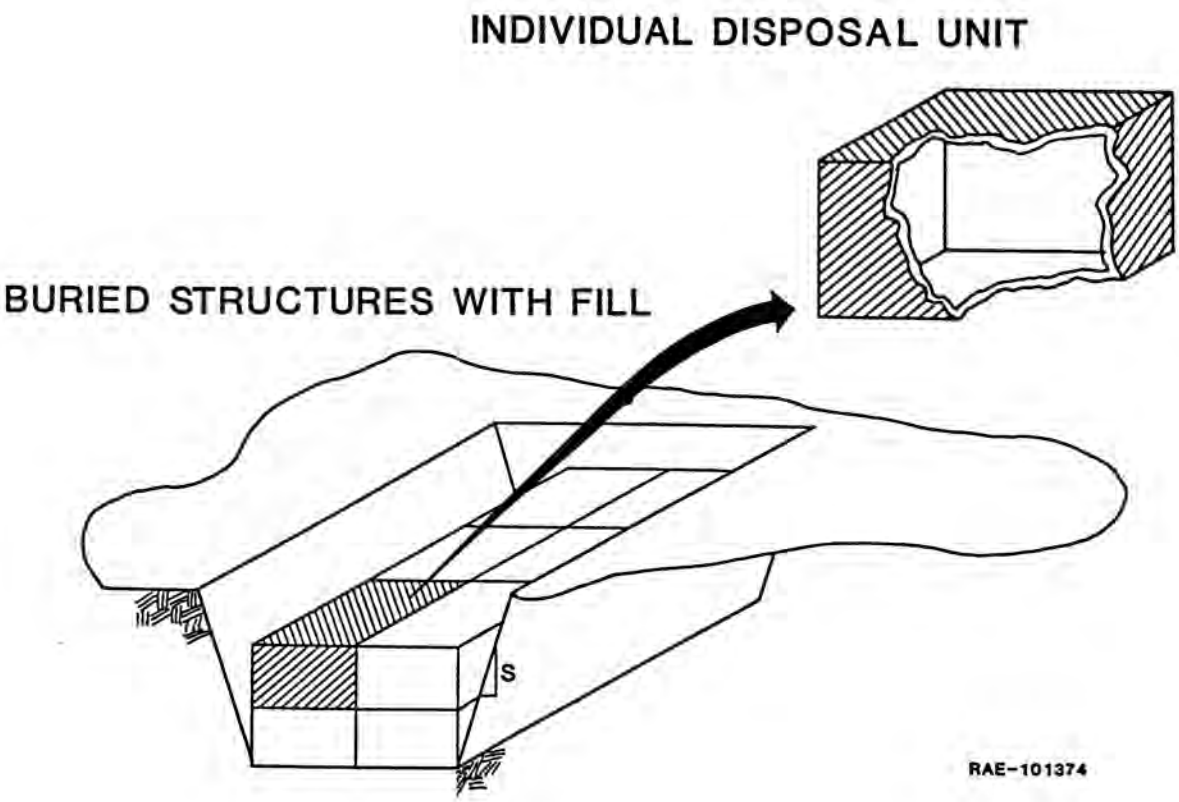

Fig. 2. Schematic of Major Disposal Unit

The efficiency of waste placement within a canister for Buried Modules with Fill disposal was conservatively estimated to be about 60 percent. Considering the volume occupied by the canister, the overall efficiency of placement is about 30 percent.

RELATIVE PERFORMANCE EVALUATION OF DISPOSAL TECHNOLOGIES

A variety of generic computer models have been used for the performance assessment of several disposal technologies. In general, the environment modeled for the disposal technologies may be conveniently divided into near-field and far-field aspects. The former refers to simulation of the disposal technology itself. Radionuclide migration is projected from the waste to just outside of the boundaries of the disposal unit.

Far-field projections begin with these near-field release rates and simulate subsequent movement to more distant locations. Transport may involve atmospheric, biologic, and hydrologic vectors, ultimately resulting in the exposure of human receptors.

It is apparent that each of these aspects must be addressed by a code if it is to adequately assess a given disposal technology. However, while numerous codes collectively address far-field mechanisms addequately, near-field simulation technology is in a relatively undeveloped stage. Virtually all of the generic codes simulate releases from the facility ultimately with very simple models. As shown in Fig. 3, these parameters relate to the infiltration rate, P, the nuclide inventory, I, the fractional leach rate, F, and the water outflow rate from the facility, W. The fractional leach rate can take two forms - a constant under all conditions, or one that describes a constant nuclide concentration partitioning between solid and liquid phases in the facility.

The result of the latter mechanism is a fractional leach rate that is directly proportional to the infiltration rate. The effects of enhanced barriers such as concrete modules or concrete structure are modeled by varying either P, F, or W. In general, the near-field modeling is not sufficient to allow an adequate comparison of the relative safety performance of different disposal technologies.

SUMMARY

The generic conceptual designs presented in this paper will form the basis for forthcoming assessments to be conducted for EPRI. Computer codes more capable of distinguishing the performance chracteristics of LLW disposal technologies will also be developed by EPRI.

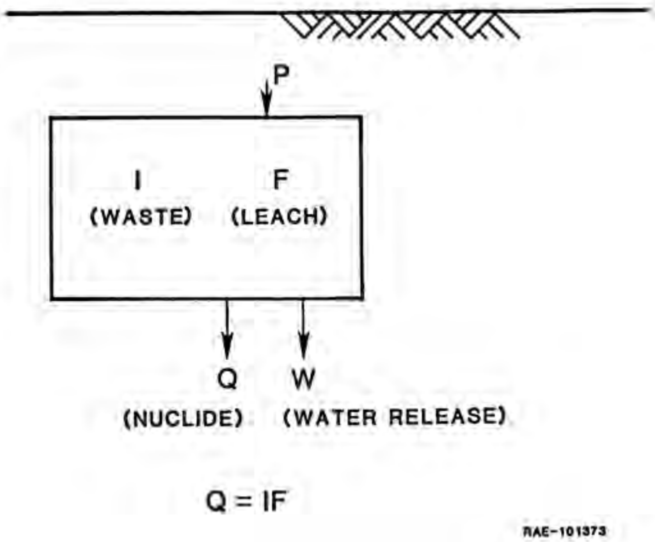

Fig. 3. Basic Parameters Describing Release From a Waste Facility

The efforts of the Coordinating Committee for LLW Disposal Technology have produced benefit to independent researchers and developers.

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