DEPARTMENT OF ENERGY LOW-LEVEL WASTE DISPOSAL:

ADAPTING TO A CHANGING ENVIRONMENT

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ABSTRACT

The Department of Energy (DOE) operates perhaps the largest low-level waste management (LLWM) system in the world, consisting of more than 20 waste generating sites and 6 major disposal sites, which disposed of more than 2 million cubic meters of low-level waste (LLW) in 1984. The DOE issued Order 5820.2 in 1984 to regulate the disposal of all DOE radioactive waste. This Order left many specific decisions to the Operations Offices in recognition of the wide diversity of geology and climate, as well as in the nature and quantity of waste streams, which must be managed by the various offices.

There is increased reliance on engineered barriers in the disposal of LLW in foreign countries and in some of the anticipated disposal facilities for the U.S. regional compacts. Engineered features, including both waste stabilization and site improvements, are permitted under DOE's Order 5820.2. To encourage the most efficient use of available space and to meet the demands for more reliable prediction of performance, the incorporation of both advanced waste treatment and stabilization techniques and engineered site improvements will be required by DOE in the future.

The DOE plans to use a systems approach which will involve attempting to obtain consensus on performance requirements among the regulatory bodies involved and applying these performance requirements in determining the best available site. Engineered features will be added either through the stabilization of the waste or site improvements as required to meet the performance requirements. Stabilization requirements will be incorporated into the waste acceptance criteria as necessary, relieving the disposal site operator from making continual cost-effectiveness decisions. The initial analysis to determine a configuration which meets minimum performance requirements will also serve as the baseline for additional analyses to meet the as-low-as-reasonably-achievable (ALARA) requirements.

The states are becoming more active in the regulation of ground and surface waters from DOE waste management activities within their jurisdictions. The state limitations on water contamination and the required assurance that the contamination limits will be met are a source of considerable difficulty for DOE sites that need to establish new disposal facilities. The states are also concerned with the concentration in ground or surface water at the point of contamination rather than the eventual dose to the public. Increasingly, sites suitable for shallow land burial on DOE reservations in humid regions of the country are becoming scarce.

INTRODUCTION

The DOE operates perhaps the largest LLW management system in the world, consisting of more than 20 waste generating sites and 6 major disposal sites which disposed of more than 2 million cubic meters of LLW in 1984. Over the course of our 40-year operational history, we have seen tremendous changes both in the state-of-the-art of waste management technologies and public and regulatory agencies' attitudes toward waste management. The policy of DOE and its predecessor agencies is, and always has been, to dispose of waste in a safe and environmentally acceptable manner. However, the Department's philosophy on LLW is evolving, reflecting the experience gained from past practices, the improvements in available technology, and an evolving regulatory environment. The DOE issued Order 5820.2 in 1984 to regulate the disposal of all DOE radioactive waste. This Order left many specific decisions to the DOE Operations Offices in recognition of the wide diversity of geology and climate, as well as in the nature and quantity of waste streams, which must be handled by the various offices. Additional guidance for implementing the Order, which should assure improved performance in the future, is now being issued.

Early workers in the LLW disposal field were supporting urgent national defense goals and had no precedents from which to work; consequently, they tried to minimize any impacts of their waste management activities on their primary mission. In the very early days, few envisioned the eventual scope of the nuclear energy programs or the total quantities of waste that would eventually be generated. The early LLW disposal operations have resulted in a number of disposal sites that require continuing maintenance and monitoring. The cost of potential corrective actions within the DOE system could be significant, and problems associated with placing these sites in a stable condition requiring minimum maintenance over the decay period of the waste are just beginning to be addressed.

The history of waste management in the DOE system is one of continuous evolution to apply the best and most cost-effective technology as it reaches the application stage. The performance of existing disposal sites is continuously monitored to determine the need for instituting corrective measures, as well as to guide the development of improved technology. Active development programs address site-specific and generic needs for corrective actions and for future operations. Indeed, the analysis of corrective needs and the effectiveness of corrective measures is one of the most valuable sources for guidance in the development of improved technology. The DOE, of course, maintains close contact with commercial and international developments in waste management technology. All of these activities influence the future direction of the DOE waste management system. One of the major responsibilities for DOE is to answer the institutional question of how such a diverse system is to be regulated while still permitting improvements to be incorporated. Overly prescriptive regulation obviously fails in two ways: (1) the length and detail require prohibitive resources to prepare, update, and implement; and (2) the regulation would not be easily adapted to site-specific requirements and changes in technology.

CURRENT PRACTICE BY DOE

Shallow Land Burial

One of the most attractive features of shallow land burial is low cost. If a suitable site is available, this mode of disposal is probably the least expensive of all those that have been investigated. This cost aspect of shallow land burial was no doubt a strong influence in its early selection and its continuing application. However, improper site selection or improper development of a site can end up being very expensive because of the continuing cost of corrective actions. In general, arid sites with great depth to the ground water and large buffer zones are not very demanding in their development. Sites with high annual rainfall, shallow water tables, and high population densities require more care.

Greater Confinement Disposal

Even the best sites may not be suitable for the shallow land burial of some high-activity LLW. These materials usually require disposal which provides greater isolation than conventional shallow land burial. As presently practiced at DOE sites, greater confinement disposal generally involves a vertical borehole with a concrete cap to provide greater shielding and reduce the possibility of intentional or inadvertent intrusion. Some greater confinement disposal methods incorporate barriers to prevent contact between the waste and ground water. The basic principle is to dispose of waste at greater depths and to incorporate engineered barriers to prevent migration of the waste or inadvertent intrusion. Engineered barriers must be designed for a specific site and waste type. Greater confinement disposal is primarily an enhancement of the disposal site; and while it may make a broader range of sites suitable for disposal of a given waste, it does not make LLW disposal totally site independent. Some specific site conditions, such as the presence of faults and floodplains, cannot easily and cost effectively be engineered for.

Problems Related to Past DOE Practices

Past practices in the disposal of DOE and commercial waste by shallow land burial at some sites have led to problems that require corrective action. Problems are usually related to the waste form and its emplacement. Corrosion of partially filled containers and decay of organic material eventually destroy the structural integrity of the waste and its container and allow the overburden to collapse into the void space. A collapse can propagate to the surface, exposing the waste to dispersive action by man, animals, and weather and opening a direct channel for water to enter the burial trench. Even a slumping of the surface will disrupt the trench cap and form a pocket for water to accumulate and percolate into the trench. Inactive DOE burial sites are inspected regularly for subsidence so that they can be repaired by filling and tamping. The solution to this problem is to use a stabilized waste form and/or better emplacement.

Water intrusion into the trench through the bottom or sidewalls is a problem directly related to the site and the design of the disposal unit. This occurs when a shallow water table is elevated by seasonal fluctuation so that it intersects the trench. One successful corrective measure for this problem is the installation of passive drains to intercept and divert the ground water. To avoid this problem, better characterization of the ground water behavior at the site and installation of ground water control measures at the time of development can be employed.

Surface water can percolate through a poorly designed or poorly installed trench cap. Some sites can tolerate small amounts of percolation; however, if the formation in which the trench is excavated is less permeable than the trench cap, a net accumulation of water will occur in the trench. The water standing in trench voids can dissolve more radionuclides than if it percolated on through the trench bottom. A fresh charge of water from the next rain can force the contaminated water back to the surface. This process, known as the bathtub effect, results in the waste being directly available for surface dispersion. The problem can be corrected by filling the voids in the trench by tamping, injecting cement or other material, and installing an impermeable trench cap. It is better to avoid sites with such permeability characteristics.

Other problems have been encountered that contribute to high maintenance costs. These can be avoided by proper design, operation, and waste treatment practices. In general, it will be less expensive in the long run to anticipate and avoid these problems than it will be to correct them as they appear. In particular, the site selection, design, and operation should anticipate the less expensive closure of the disposal site, i.e., placing the site in a minimum maintenance configuration for the period of institutional control. The requirements for monitoring after closure should also be considered from the start.

FUTURE DIRECTIONS IN INTERNATIONAL WASTE MANAGEMENT

In the United States and in foreign countries, there is a growing perception by the public that the performance of engineered systems can be more reliably analyzed and better predicted than natural systems. While this perception is not invariably true, it has no doubt influenced the direction of waste disposal technology both in the United States and abroad. In Europe, several countries are either operating or constructing highly engineered facilities. In addition, several regional compacts are considering requirements for facilities that will incorporate engineered barriers to avoid the migration of waste.

In July 1983, Sweden began construction of an underground repository to dispose of their low-level radioactive waste through the year 2010. The repository, which is under the sea about 1 km from the shore, has at least 50 m of rock cover between the cavern and the seabed. This approach was chosen for several reasons: (1) there is a shortage of suitable sites for shallow land burial in Sweden; (2) Sweden did not want to make the commitment to the institutional control period required with shallow land burial; (3) sea dumping is forbidden by law in Sweden; and (4) Sweden has an abundance of suitable rock and considerable experience in its excavation. It should be noted that Sweden is also considering the onsite disposal of some of the lowest activity waste at reactor sites.

Since 1978, the French have utilized a near-surface and an above-ground approach to LLW disposal, which they term the "earth-mounded concrete bunker." The high-activity waste is placed in concrete bunkers below the ground surface level and is filled with concrete to form a monolith. Lower activity waste, which can be contact-handled, is stacked on top of the bunkers at about the original level of the ground surface, to form a tumulus. Any water that percolates through the waste is collected, monitored, and treated if required. The completed tumulus is covered with a sealer layer of clay, a layer of topsoil, and then is revegetated.

The Federal Republic of Germany has had considerable experience with deep geologic disposal at the Asse salt mine. They appear to be committed to geologic disposal of all radioactive waste. The location has not been selected, but it will probably be in an abandoned iron mine.

The Canadians have disposed of some LLW by shallow land burial at the Chalk River National Laboratory, but most of their commercial waste, associated with the operations of Ontario Hydro Co., is in storage at the Bruce Nuclear Power Facility. The lowest activity waste is stored in a prefabricated concrete warehouse at ground level. Higher activity waste is stored in concrete-lined trenches. The highest activity waste is stored in concrete-shielded cells or in vertical cylindrical holes with shielded plugs, called tileholes. The low-activity waste is treated by incineration or compaction, when appropriate, prior to storage. All of the waste is retrievable and will be transferred to permanent disposal when the site and mode of disposal are selected. Waste from other nuclear facilities operated by Ontario Hydro is shipped to the Bruce facility for treatment and storage.

The Japanese have not selected a final mode or site for the disposal of LLW. They are concentrating on waste treatment to obtain maximum volume reduction. Waste is treated as it is generated and will be stored until the disposal mode is selected.

NEED FOR NEW DOE DISPOSAL FACILITIES

Increasingly, the sites on some DOE reservations suitable for shallow land burial are becoming scarce, especially in humid regions of the country. The states are becoming more active in the regulation of DOE waste management facilities through their jurisdiction over the ground and surface waters. The state limitations on water contamination and the required assurance that the contamination limits will be met are a source of considerable difficulty for DOE sites that need to establish new disposal facilities. The states are also concerned with the concentration in ground or surface water at the point of discharge rather than the eventual dose to the public.

Consideration of the point of discharge rather than the point of public exposure negates much of the mitigating effects of shallow land burial, i.e., the adsorption on soil and the slow movement of ground water. The result is that the magnitude of the source term, represented by the buried waste as stabilized, and the effect of any engineered barriers must be more carefully controlled and more precisely known than has been the practice in the past.

SYSTEMS APPROACH TO LLW DISPOSAL/A NEW PHILOSOPHY

Obviously there has been considerable activity in the United States and abroad on the application of improved waste treatment for storage or disposal and the application of engineered barriers to intrusion or waste migration. Cost recovery within the DOE and the past availability of sites have not encouraged the maximum application of existing technology. The increasing scarcity of good sites, the cost of continuing maintenance, and the increasingly complicated regulatory requirements forged a new attitude.

The new waste management philosophy to be adopted across the DOE system, as stated in the additional guidance being issued for the implementation of DOE Order 5820.2, clearly emphasizes a systems approach to waste management. This approach considers the individual and synergistic effects of the various steps in waste management from generation to treatment to final disposal. Near-term and long-term costs versus performance must be evaluated on a systems basis.

The guidance, coupled with DOE Order 5820.2, provides the framework for implementing such a systems approach.

Specifically, the guidance establishes an interim performance objective of 25 mrem/year to the off-site public. This is comparable to the Nuclear Regulatory Commission regulations applicable to the commercial sector and eliminates a potential source of criticism. Second, a documented systems analysis in support of establishing new facilities is required. This analysis must balance the near-term costs and benefits of engineered enhancements with long-term costs and benefits of improved performance. Third, an auditable waste generation reduction program must be implemented.

The DOE expects to use a systems approach that will involve attempting to obtain a consensus on site-specific performance requirements among the regulatory bodies involved and then applying these performance requirements in determining the best available site. Engineered features will be added either through the stabilization of the waste or site improvements as required to meet the performance requirements. Stabilization requirements will be incorporated into the waste acceptance criteria as necessary, relieving the disposal site operator from continuing cost-effectiveness decisions. The initial analysis to determine a configuration that meets minimum performance requirements will also serve as the baseline for additional analyses to meet the ALARA requirements.

Since the objective of LLW disposal is to isolate the waste over the time period during which it is potentially harmful, the best way to regulate the activity is on the basis of performance evaluation. The legally binding performance requirement will be eventually set by the Environmental Protection Agency (EPA). We will be using a requirement of 25 mrem per year to the off-site public as an interim guidance value pending issuance by EPA of its standard. Achieving the performance requirement will involve a combination of the disposal site's inherent performance and the contributions of the engineered barriers and waste stabilization requirements.

The systems approach will start by determining the most restrictive criterion of performance for a candidate site. Pathways analysis will be used to determine what source term the site can accommodate and still meet this performance criterion. The combination of engineered barriers and waste stabilization required to accommodate this source term will then be determined. The base level of cost/performance will be determined from site development and waste preparation costs. The cost of further enhancing performance can be analyzed consistent with the ALARA concept. If further enhancement proves reasonable, it will be applied. The waste acceptance criteria are determined in accordance with the performance analysis. Past analyses of performance have not taken credit for stabilized waste forms, and engineered barriers have been installed after the fact as corrective actions at marginal or poorly performing sites. We feel that the site should be selected, developed, and operated to provide a system to permit optimal and cost-effective application of all aspects of the technology. Both waste stabilization and engineered improvements can be applied under DOE's Order 5820.2. In the past, the use of such features was judged on their immediate cost effectiveness; but since land was available and little value was placed on it, engineered features were seldom employed. To encourage the most efficient use of available space and to meet the demands for more quantitative prediction of performance, the incorporation of advanced waste treatment and stabilization techniques and engineered improvements will be required in the future.

CONCLUSION

The DOE LLW policy is to dispose of LLW in a safe and environmentally acceptable manner. Technical implementation of the policy in the past has not always been completely satisfactory in that some practices have contributed to high continuing maintenance costs, and it is expensive to correct deficiencies of earlier operations. The trend in foreign waste disposal and in U.S. commercial disposal under the regional compacts appears to be toward a greater reliance on engineered barriers to the migration of waste. Improvements have been made in the DOE LLW operations, but application of the best technology has sometimes been hampered because of the lack of a systems approach to the siting, design, and operation of DOE LLW disposal facilities until now. A systems approach to the siting, design, and operation of waste disposal sites will assure better system performance and a better application of ALARA.