Disposal Concepts and Characteristics of Existing and Potential Low-Level Waste Repositories - 9076

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ABSTRACT

The closure of the Barnwell low-level waste (LLW) disposal facility to non-Atlantic Compact users poses significant problems for organizations seeking to remove waste material from public circulation. Beta-gamma sources such as ^{137}Cs and ^{90}Sr in particular create problems because in 36 states no path forward exists for disposal. Furthermore, several other countries are considering disposition of sealed sources in a variety of facilities. Like much of the United States, many of these countries currently have no means of disposal. Consequently, there is a greater tendency for sources to be misplaced or stored in insufficient facilities, resulting in an increased likelihood of unwitting exposure of nearby people to radioactive materials. This paper provides an overview of the various disposal concepts that have been employed or attempted in the United States. From these concepts, a general overview of characteristics necessary for long-term disposal is synthesized.

INTRODUCTION

At the end of the 2007 fiscal year, the Barnwell Low-Level Waste (LLW) disposal facility in South Carolina closed its doors to all non-Atlantic Compact users. Although other means exist for disposition of Class A waste and any transuranic (TRU) waste that is classified as Defense waste, many forms of Class B and Class C waste have no path forward for final disposition. Lack of such a disposal pathway creates a two-fold problem. First, existing sources are either stored on-site indefinitely, accruing high costs, or are abandoned (1, 2). Second, the lack of a disposal pathway is a major barrier to companies for acquiring new sources. Potentially, the beneficial uses of sealed sources may be overshadowed by the lack of disposition options.

The United States is not unique in lacking disposal pathways. Particularly for sealed sources, very few nations are equipped to dispose of sealed sources. A few attempts have begun to develop small-scale facilities that can handle a few sources, such as boreholes (3). While each country facing the disposal problem must deal with unique issues, any repository must be evaluated for its ability to prevent exposure of the sources, both via accidental intrusion into the facility and leakage of the stored material.

Weapons waste and spent nuclear fuel have, in the United States and elsewhere, been directed towards geological repositories (4). Facilities such as the Yucca Mountain site in Nevada and the Onkalo site in Finland have undergone considerable study for purposes of ensuring that nearby population centers are unlikely to be affected to a significant degree. Although the safety of individual sites is generally hotly debated, the criterion by which the safety of sites is measured is still useful. As such, this paper will focus on the desirable characteristics of a waste repository facility, not the social or political criterion of site selection.

One fundamental assumption of this work is that many of the characteristics of safe repositories are universally applicable independent of the type of waste contained within—that is, a the characteristics of a geological repository that can securely and safely store spent nuclear fuel are assumed to be safe for a radioteletherapy head. With that assumption established, research into concepts of applied and theoretical disposition concepts for both high-level and low-level waste can constrain the desirable characteristics of future LLW repositories.

Applying these concepts to the various states and compacts that have no disposition pathway is difficult primarily due to the magnitude of the task. Site selection requires detailed knowledge of geology, social dynamics, and climate studies. In particular, geological knowledge at the level required is not within the scope of this project. For this overview, our intent is to provide a basic discussion of the general characteristics of disposal facilities.

DISPOSAL CONCEPTS

Hanford, WA (5)

The disposal facility in Hanford, Washington uses a system of engineered barriers in shallow sediment to isolate and protect the disposed waste. It is situated on sediment from recent (Tertiary) fluvial activity, in a setting dominated mainly by the Columbia River flood basalt formation. Most of the aquifer of the region is unconfined, although some areas that are below the level of the basalt behave as though they are confined. Flooding is a minor risk in the southwest portion of the facility but otherwise is not an issue. The area is structurally complex, including anticlinal folds in the north, south, and west corners and a monocline in the east.

Barnwell, SC (6)

Barnwell places sources in shallow engineered trenches. Due to the location of the facility in a relatively wet area with a shallow aquifer, engineered barriers provide the primary protection for the sources. Flooding is much more of a concern with this facility, as are issues with groundwater contamination and large nearby population centers. The Barnwell facility represents a conceptual end-member wherein reliance is placed upon manmade structures and protections with the natural setting being more of an impediment than a benefit.

Waste Isolation Pilot Plant, NM (7)

The Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico implants waste deep underground in crystalline salt. Fluid flow is prevented by the impermeable salt unit. WIPP employs engineered barriers as part of a policy of defense-in-depth, wherein the natural impermeability of the salt is augmented by further barriers to fluid entry and then the containers the sources are emplaced in. Containers are placed in carved caverns which are then collapsed when they reach their storage capacity.

Nevada Test Site, NV (8)

Nevada Test Site has a number of “greater confinement” boreholes containing very high activities (around 8 million curies) of different types of waste. The boreholes are drilled into alluvial fans near the deposits from a playa lake, on a closed basin. They are well above the water table in a region with very low precipitation. The basin is internally drained and does not have an outlet to any fluvial systems that reach the Pacific Ocean. Seismic activity is moderately high. The boreholes themselves are around three meters in diameter and do not have any form of lining. Alluvium caps were placed on top of the holes to deter future intrusion. Structure in the region is complicated, with mountain ranges running north-south and valleys between. The boreholes are in a quiet area between two major fault boundaries. Overall, NTS represents the opposite end of the spectrum from Barnwell, with the geologic setting serving as the primary means of defense.

Yucca Mountain, NV (9)

Yucca Mountain is the US government's primary intended repository for high-level waste including spent nuclear fuel and weapons waste. As a facility intended for disposal of high-level sources, Yucca Mountain has unique challenges, particularly in light of public opinion. Despite these challenges, the conceptual setting of the facility is useful to consider. Much like the NTS boreholes, Yucca Mountain is set in an arid, desert region with a low water table. The facility itself is in a tuff unit whose safety and ability to retain the sources within is contested; validity of the arguments on both sides is questionable owing to the highly passionate nature of the subject. Conceptually, however, Yucca Mountain is supposed to be a defense-in-depth facility with engineered barriers augmenting geology.

GEOLOGIC CRITERIA FOR FACILITIES

Hydrology

Hydrologically, the primary goal of any disposal facility is to prevent the infiltration of radioactive materials into groundwater or other fluids passing through the subsurface. Such leakage, particularly in a permeable, connected aquifer, may lead to the exposure of even distant populations to radioactive material. To this end, the setting of any geologic repository should emplace waste in units that are as impermeable as possible. The facility should also have a low hydraulic gradient to slow the spread of any leaks. Annual precipitation should be minimized if possible, particularly for shallow disposal facilities. Furthermore, the area should have limited other uses; for example, there should not be any petroleum, water, or mineral resources that would give future generations reason to be active in the area and risk exposure to the sources.

Structure

Necessary structural characteristics are dependent on the type of host rock selected. For example, the WIPP facility is emplaced in a salt dome (7), whereas Yucca Mountain seeks to use the flattest, least deformed tuff mesa possible (9). Despite this considerable variation, a few desirable structural traits can be identified. Of these, the most important is that the area should not be deformed in such a way that there are abundant pathways for fluids; in general, the variations among the facilities are simply a means of achieving this. WIPP, for example, relies on the plastic deformation of the surrounding salt to seal any pathways that do form, while Yucca Mountain, Hanford, and others attempt to avoid such pathways in the first place. Fractures and faults associated with structural deformation should be minimized to prevent escape of stored materials through these pathways. Engineered barriers can help compensate for any weaknesses in this regard, but a defense-in-depth policy dictates that structural features are very important.

Tectonic Stability

The long-term stability of an area is a vital characteristic of any facility and frequently, as in the case of Yucca Mountain, can be a major source of contention in the fight to develop a facility. Long term tectonic quiescence of a facility is important for preventing undue stresses on waste containers and the rocks surrounding the disposed waste. In particular, regions with active volcanism and seismically unstable regions have drawn criticism as potential repository sites. Seismic hazards are very difficult to gauge due to the difficulties involved both in understanding past seismic activity in a region and in forecasting future activity. Fault mechanics are hotly contested and models vary greatly, with the result that the utility of any prediction model, particularly for long intervals between earthquakes, is nearly impossible to determine (11). Fault zones are defined as "active" if an event has occurred within the

Holocene epoch (i.e within the past ten thousand years), but such a definition is misleading and fails to take into account the possibility of longer recurrence intervals. Neotectonics presents one of the most challenging problems for site selection.

Population density

Regions with high populations create three major problems. First, the presence of so many people nearby substantially raises the risk of accidental exposure, particularly during periods in which waste is being put into the facility. Second, any leakage or escape of material is likely to more quickly affect the nearby population centers with more damaging consequences. Third, the ever-present demand for water in highly populated areas substantially increases the risk of future accidental intrusion into the disposal site via drilling. These factors in tandem indicate that regions with high population densities should be avoided. No apparent regulatory definition for the maximum acceptable population density has been declared; the general condition stated in site evaluations is to minimize the number of people nearby, but the definitions of both what an acceptable number of people is and how close they can be remains open. The most recent disposal facility, the WCS Texas facility in Andrews County, TX, is located in an area in which 90,000 people live within a 30-mile radius, including a town of 2,500 within six miles (12).

CONCLUSION

The precedent set by other disposal facilities provides vital, basic background information for any future work that may be done to prepare a pathway for Class B and C waste. Any state or compact that seeks to build a storage facility must define within a regulatory framework exactly what characteristics it desires for that facility. In order to do this, the fundamental categories discussed here are the basic questions that must be addressed on the technical side. If each of these basic categories cannot be adequately addressed, a facility is unlikely to be safe enough to overcome political and popular dissent. Given the removal of the Barnwell facility option, many states and compacts may need to develop some means of disposal pathway.

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