Building Confidence in Performance Assessments - 11394

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ABSTRACT

Continuous improvement in understanding and design of low level radioactive waste disposal cells is important to ensuring that all disposal operations continue in their purpose of protecting the public and environment from radiation hazards associated with legacy radioactive waste. Given the relatively short amount of time that low level radioactive waste disposal cells have been in operation in comparison to their compliance periods, it is important to continue to reduce the long-term uncertainty associated with disposal cells in order to build confidence in their ability to protect public health and the environment. This paper discusses the current methods used to build confidence in disposal cell performance assessments and new approaches that would further contribute to this goal. Emphasis is placed on the current methods used by the Department of Energy under DOE Order 435.1 to build confidence in disposal cell performance assessments, along with proposed concepts, such as monitoring for performance in addition to compliance and the use of event trees to identify important disposal cell risk-drivers, that would further build confidence in long-term performance assessment.

INTRODUCTION

Since the first nuclear facilities were built as part of the Manhattan Project, the United States Department of Energy has been dealing with the vast problem of safely disposing and managing the growing volume of radioactive waste that is produced from nuclear activities. Today, after decades of nuclear research and weapons production, there remain large deposits of radioactive material on DOE sites across the country. This waste requires isolation for an extended period of time in order to reduce its risk to human health and the environment to acceptable levels. While high-level waste and spent fuel require hundreds of thousands of years of isolation in a deep geologic repository, low-level waste can be sufficiently isolated and managed in near-surface disposal facilities. These facilities, also known as disposal cells, use a combination of different engineered barriers coupled together to insure that the waste is isolated during the compliance period, which for low-level waste (LLW) is 1,000 years [1,2]. LLW disposal cells are required to be robust, able to withstand all of the rigors associated with exposure to the environment, while continuing to perform at a level required to meet all performance objectives.

However, the period of compliance remains a challenge. Currently favored design approaches have only been in existence for a few decades and there is still uncertainty about the long-term performance under the conditions present at a given DOE waste site. Since the movement of waste within a disposal cell is designed to be slow, detection of a problem with the engineered barriers separating the waste from the environment would not potentially occur until after waste began to leak from the disposal cell if vadose zone and groundwater monitoring are the only

types of monitoring employed. Given the multimillion-dollar investment needed to construct a disposal cell and the difficulty of repairing a failure after the system is installed, more of an early warning that focuses on potential precursors to system degradation is needed. Furthermore, there is a large difference between the institutional control period of 100 years and the compliance period of 1000 years. Problems with a disposal cell during the institutional control period, during which the site is actively monitored, will at least have human interaction available to attempt to solve any issues that could arise. Once this period is over, however, any problem that takes longer to develop could proceed unchecked, with potential adverse consequences. Working towards a solution to these problems lies in the continued reduction of uncertainties in short and long-term disposal cell performance through a combination of efforts, such as a better understanding of environmental processes at sites and engineered barrier evolution over time. This paper provides an overview of how the DOE currently works to progressively increase confidence in performance assessments and discusses a few proposed methods for further building confidence in the performance assessment.

CURRENT PRACTICES

Under the Atomic Energy Act of 1954, the United States Department of Energy has the authority to internally regulate low-level radioactive waste that was generated as a result of defense activities [3]. This process has evolved over time, and currently the DOE has a robust system in place to handle the process of low-level radioactive waste disposal at sites around the DOE complex. The present system, established under the authority and direction of DOE Order 435.1, employs a multistep approach to ensuring that the disposal cell will achieve the required performance objectives. This process must be completed in order for a disposal facility to be authorized to operate. Performance objectives are defined within DOE Order 435.1, and are based on the main risk drivers at a site. One set of objectives is a mix of technical and administrative limits on the concentration at a compliance point (100m down gradient) of a given radionuclide that can be released from a disposal cell [1,2]. These concentration limits are designed to provide a sufficient amount of protection from inadvertent waste exposure to any human or environmental system at or outside 100m from the disposal site during the institutional control phase. A second set of objectives are exposure limits based on the "Inadvertent Intruder Scenario", which assumes that an individual inadvertently either builds a living structure directly on top of the disposal cell or drills a well through the disposal cell once institutional controls are no longer present. As with the first set, these objectives are also meant to provide a boundary of acceptable exposure to radionuclides should the scenario occur.

Demonstration that performance objectives will be met is accomplished though the production of a series of documents that govern all aspects of waste disposal for a given low-level radioactive waste site [1,2,4]. The DOE Radioactive Waste Management Manual outlines how each required document is to be prepared for the design, construction, operation and closure of a near surface disposal cell for radioactive waste [2]. The main document, the Performance Assessment (PA), involves all of the studies and analysis at the specific disposal cell or cells within a site, and documents how that disposal cell will meet performance objectives over the compliance period [1,6,7]. In addition to the PA, the regulations require the preparation of several other documents including a Composite Analysis (CA), a Closure Plan, a Long Term Storage and Maintenance Plan and Annual Summaries. The Composite Analysis (CA) evaluates all sources

of radioactive contamination across an entire site that are projected to remain once site operations have been completed and ensures that members of the public will have sufficient radiological protection from the cumulative dose effects of these sources [1,8]. The Closure Plan provides information concerning the steps that will be taken to close the facility following the completion of waste disposal operations [1,9]. The Long Term Storage and Maintenance plan addresses the implementation of institutional controls and compliance monitoring. Finally Annual Summaries, produced on a yearly basis, provide information concerning the performance of the facility over the period addressed [1,10,11,12]. Included in these summaries is an inventory of waste disposed to date, monitoring results, and brief overviews of results from new or other ongoing studies. In addition, the summaries can include recommendations on the need for whether further investigations, including the possibility of revising parts or the entire Performance Assessment. Each document is initially drafted by site technical staff, then reviewed and approved by the DOE's internal oversight panel. For low-level radioactive waste the Low Level Waste Disposal Facility Federal Review Group (LFRG) serves this function [1,2]. The LFRG group consists of a mix of headquarters and field staff. In order for a host site to receive a Disposal Authorization Statement indicating they have the authority to begin placing waste within a disposal cell, the LFRG must have voted on approval for that site's requisite PA or CA.

In order to take advantage of continuing site studies and advances in understanding of how disposal cells change over time and how waste constituents migrate through the surrounding environment, these documents are continuously being reviewed, amended, and updated. This process, referred to as "Performance Assessment Maintenance," assists in building confidence in the disposal operations and long-term performance assessment of a disposal cell through a wide variety of activities. These activities are intended to reduce the uncertainty and confirm key assumptions in long-term assessments of disposal cell performance [5]. One example of this is site environmental monitoring activities, which provide points of comparison between computer modeling and actual field results to assess that disposal cell performance is conforming to modeling results from the PA analysis. Another example is the construction of test beds to carry out field experiments, such as the Hanford barrier experiments in Richland and the performance monitoring experiments being conducted at Idaho [5,10]. A third example is laboratory and field experiments testing the effects of long-term environmental exposure to waste forms and barrier components, such as the B-25 box experiments at Savannah River [13]. One final example is supplemental analysis to address problems that were not anticipated in the original PA, such as that on vault 4 of the Z-area (Saltstone) disposal operations at Savannah River, which in part lead to the recent revision of the Saltstone Performance Assessment [14].

In the more than 11 years since DOE Order 435.1 was issued in 1999, there have been a number of Performance Assessments constructed under the regulatory regime of the Order, such as The E-Area Low-Level Waste Facility DOE 435.1 Performance Assessment [6] and the F-Tank Farm DOE 435.1 Performance Assessment [7], both located at the Savannah River Site. As time has passed lessons learned from the implementation of the Order, along with changes in the structure of the DOE system, have necessitated a review of the Order with an eye towards improving portions during a revision process [5]. Led by the DOE Office of Environmental Management, the process of updating the Order was begun in early 2008 [15]. The first production from the assembled team of radioactive waste management experts and project management consultants

was an identification of over 15 specific areas of the Order's Directives Package that would benefit from an update process. This paper will focus on two key concepts in the area of Performance Assessment Maintenance: the role of "performance" monitoring and the need for development of flexible methodologies that could be used to address various aspects of consistency in Performance Assessments and disposal cell designs during all phases of the PA process [16].

IMPROVING PERFORMANCE CONFIRMATION

During the process of conducting a Performance Assessment, site technical staff draw on previous laboratory studies and site-specific field studies to estimate the evolution of the disposal cell during the compliance period using numerical modeling software packages based on site-specific parameters [6,7]. Inputs to these models can for example include the underlying hydrology of the site (such as depth to groundwater), the amount and duration of precipitation, and the properties of the soil surrounding the disposal cell. Site design specifications and waste acceptance criteria can be optimized for the specific conditions present at the site to determine the amount of waste to be disposed of in a safe manner. One issue with this process, however, is that currently it's driven by technical staff at each site that may operate independently of the other DOE sties, creating a site by site approach to Performance Assessments, sometimes with variations between disposal operations at a same site [16]. This can involve the use of different modeling packages to be used with site-specific conceptual models and preferences for a given disposal cell design type. While some of this makes sense, as each site is different, a lack of consistency with the approach towards a performance assessment makes it more difficult to compare and validate PA decisions and results between sites. This in turn lowers transparency in the PA process and can lead to lower regulatory and public confidence in meeting performance objectives [16]. The recent debate within the DOE about whether to use composite liners with leachate collection on some or all future disposal cells is one consequence of inconsistency between sites [17]. Though evidence suggests that some sites would receive no benefit from the inclusion of a liner system, low public confidence in radioactive waste disposal has led to the call for all sites to be lined. A scientific risk-based methodology that could be applied consistently to all sites and was quantitative to allow for transparency would therefore be a valuable tool for improving performance confirmation.

Once a disposal cell is constructed, the environment around the site (for instance groundwater and vadose zone pore water) is required to be monitored for compliance with the appropriate regulations in Order 435.1. Indicator concentrations based on modeling results in the performance assessment are used to provide points of reference between the PA and actual monitoring results [5]. Data from compliance monitoring is typically limited to concentrations of contaminants in air and water outside of the disposal cell, and therefore this type of monitoring is also limited in its ability to assess the overall health of the disposal cell and each engineered component. The use of performance monitoring is an additional set of tools that has the potential to provide greater insight into the health and evolution of a disposal cell [5]. Performance monitoring differs from compliance monitoring in that it covers a much broader range of parameters that could indicate disposal cell performance, and could also be used to validate disposal cell function or identify potential problems much quicker than typical compliance monitoring. While the inclusion of guidance on performance monitoring is being

considered for the update to 435.1, a number of experiments are already being conducted around the DOE complex. One study at Savannah River is investigating the use of satellite imagery to detect chances in surface temperature, which could be correlated to surface moisture and then potentially to evapotranspiration rates on disposal cells [18]. Another study at Idaho is using continuous data loggers to measure the movement of moisture through a test bed cover in real-time to assess how hydraulic properties of covers change with varying climate and evolve over time [10]. Though these studies are important steps in understanding disposal cell evolution, a good portion of them are site specific. In order for them to increase their usefulness, they will need to be applicable to differing site characteristics and site disposal requirements. However, performance monitoring holds great potential in increasing understanding of disposal systems and contributing to the reduction of uncertainty in long-term performance objectives.

GOING FORWARD

Work is currently underway at Vanderbilt, through the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) to compile information on facility designs and environmental and climate features for selected current and future disposal facilities at DOE sites. Also, steps are being taken to identify performance confirmation and monitoring measures being considered at these sites, so that confidence in the PA will be increased as well. There are a number of goals associated with this work:

- The development of a quantitative risk informed decision-making methodology to determine the need for liners and leachate collection systems, along with the proper type of liner system to provide the highest level of reliability based on waste characteristics and site-specific parameters
- The creation of conceptual liner designs that would allow site engineers to better predict and monitor the evolution (degradation) of disposal cell performance based on certain characteristics
- The identification of important risk drivers and site specific scenarios appropriate to long-term performance assessment through the use of event trees
- The development of approaches appropriate to performance monitoring and long term performance confirmation
- The development of recommendations for the implementation of monitoring techniques to help reduce uncertainty in long term cell performance and validate model assumptions from the performance assessment
- The identification of parameters that can be monitored to assess future cell performance and provide information on the current status of a disposal cell

Our ultimate goal is the development of a decision making tool will that will address facility design questions e.g. the need for bottom liners and leachate collection systems, facility cover design and associated post-closure performance monitoring and confirmation.

Reducing long-term uncertainties in the performance of low-level waste disposal cells will continue to be an important goal of radioactive waste management. Performance monitoring and confirmation are needed to build understanding and confidence in key components of the PA.

Protection of human health and the environment requires that disposal cells continue to operate with a high degree of reliability over their compliance periods.

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