PERFORMANCE MANAGEMENT OF LOW-LEVEL RADIOACTIVE AND MIXED WASTE DISPOSAL

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ABSTRACT

Prediction of potential impacts to the public environment from a proposed or existing low-level radioactive or mixed wastes disposal facility is commonly referred to as performance assessment. Performance assessment usually demonstrates that a particular site and facility, given assumed waste characteristics, will meet the prescribed regulatory standards in 10 CFR Part 61 or DOE Order 5820.2A. The information collected before and the activities required for a performance assessment provide an often overlooked opportunity. Beginning with the first thought that a disposal system is needed, available information can be used for planning and evaluation to ensure that not only the performance objectives are met, but the anticipated behavior of the disposal system is understood. That allows the authorities to identify specific issues related to waste disposal and develop strategies for long-term management of wastes. We call this concept performance management and describe here how performance management is applied.

Application of performance assessment techniques early in the disposal system development process can be an effective tool to help guide the developer with waste characterization, site characterization, site enhancements (barriers), and environmental monitoring design. Early application of those techniques can help the developer establish that the proposed disposal system can be demonstrated to meet the applicable regulatory requirements. Integration of available information through performance management will allow the developer to gain a comprehensive understanding of the physical characteristics of the disposal system. This in turn will permit the developer to refine the concept of the physical system, and the mathematical representation of that system.

Early in the disposal system development process, the ability to specifically determine sensitive points of exposure are less important than the determination of overall sensitivity of the system. Later in the procedure, determination of the most sensitive points of exposure are important especially to the design of a waste acceptance criteria, engineered barriers, and a comprehensive environmental monitoring program. Periodic updates of the performance assessment during operations ensures that the original predictions hold true and a final performance assessment incorporating the actual waste inventory, information on waste form and disposal containers, final closure plans, and improved cover design specifications is developed. Those updates will provide the best available assurance that predicted performance exceeds or meets regulatory standards, while providing the developer with a comprehensive understanding of predicted disposal system behavior.

Although the RCRA hazardous and mixed low-level wastes do not have performance based requirements for disposal system development, the performance management concept can be a useful tool to improve the development process.

INTRODUCTION

Estimating potential impacts and exposures of the public to radioactive contaminants from a proposed or existing low-level radioactive or mixed wastes disposal facility by technical analysis is referred to as performance assessment. A radiological performance assessment is used to demonstrate performance objectives prescribed in regulations such as 10 CFR Part 61 or DOE Order 5820.2A. Those objectives include: 1) protection of the general population from releases of radioactivity off-site of the disposal facility, 2) protection of inadvertent intruders, 3) protection of those at or near the facility during operations, and 4) stability of the disposal facility after closure.

The purpose of a performance assessment is to demonstrate that a low-level radioactive waste disposal facility is in compliance with the regulatory requirements. For example, DOE (1) states that a performance assessment is "...a systematic analysis of the potential risks posed by waste management systems to the public and environment and a comparison of those risks to established performance objectives." That task is accomplished through technical analyses that include 1) demonstration that the general public is adequately protected from releases of radioactivity along air, soil, groundwater, surface water, plant uptake, and biotic pathways, 2) clear identification and differentiation between the roles performed by the natural disposal site characteristics and design features or enhancements used in isolating the wastes from the public and the environment, and 3) demonstration with reasonable assurance that exposures to humans will not exceed limits established by regulations.

A strategy for performance assessment was developed by NRC staff and presented in Starmer et al. (2). The strategy is generally considered to include characterization of the disposal system, including the waste to be disposed, the site, and finally the facility design, operational procedures, and administrative controls. A conceptual model is then developed that describes the important characteristics of the system and how it behaves. Based on that conceptual model, mathematical relationships are developed and equations describing those relationships are written and solved. Data gathered in the characterization phase are used to calculate impacts to humans and the environment through time and results compared to regulatory standards to illustrate compliance. The use of simple realistic models that tend to overestimate impacts and which allow examination of intermediate results lead to an understanding of the role the various components of the

system play in achieving regulatory compliance. That process is iterative, often requiring the acquisition of additional data at the site, adjustments to design and design parameters, even reformulation of the conceptual model or writing new mathematical relationships, and calculating new output values for comparison to the regulatory standards.

Even though the primary purpose of performance assessment is to demonstrate regulatory compliance, the performance assessment process can also be used to guide disposal system development, operation and overall management of a waste disposal system. Techniques used for analysis and the iterative nature contribute to management of the performance of that system. We call this concept performance management and describe here how performance management is applied.

APPLICATION

Performance management implies that the basic performance assessment approach can be used all through development, operation, and closure of a waste disposal system. Examples of use of that approach are site selection and site suitability determinations, site characterization, facility design, performance prediction, and monitoring plan development. In addition, that approach and technique can be used early for technology selection, cost/benefit analysis, updating performance estimates during operation to optimize performance, preparing the final closure plan, and if necessary for designing remedial actions.

Beginning with the first thought that a disposal system is needed, available information should be used for planning and preliminary technical evaluation to provide confidence that not only the performance objectives are met, but the anticipated behavior of the disposal system is understood. Application of performance assessment techniques early in the disposal system development process can be an effective tool to help guide the developer with waste characterization, site characterization, site enhancements (barriers), and environmental monitoring design.

Early in the disposal system development process, the ability to specifically determine sensitive points of exposure is less important than the determination of overall sensitivity of the system. That includes large scale site characteristics such as regional groundwater gradients, and generalized waste characteristics. Later in the process, determination of the most sensitive points of exposure is important especially to the design of a waste acceptance criteria, engineered barriers, and a comprehensive environmental monitoring program. In the later analysis specific waste forms and source term information are needed. Detailed site characteristics, such as localized groundwater behavior, are necessary to establish a reasonable assurance the site is appropriate for waste disposal.

Application of iterative performance assessments can help the developer establish that a proposed disposal system can be demonstrated to meet the applicable regulatory requirements. An iterative approach to performance assessment and integration of available information through performance management also allows the developer to gain a comprehensive understanding of the physical characteristics of the disposal system. This in turn permits the developer to refine the concept of the physical system, and the mathematical representation of that system. For example, all wastes for disposal may or may not be suitable for conditions at a proposed site. The performance management concept will allow the analysis of the waste with the site making it possible to determine if all wastes or a select few can or cannot be disposed. If the performance assessment reveals that a proposed site is near, or at, the exposure limits set by regulations, assessing the wastes in detail may well show the site compatible to the majority of the wastes and by disallowing a specific waste form the exposure limits are reduced to a level well below exposure limits. Inventory limits could be imposed on certain types of waste based on the performance assessment results.

Periodic updates of the performance assessment during operations ensures that the original predictions hold true. Changes in predicted performance could be used to define design or operational changes to ensure that regulatory limits are met. A final performance assessment incorporating the actual waste inventory, information on waste form and disposal containers, final closure plans, and improved cover design specifications provides the basis for a decision on final closure. Those updates will provide the best available assurance that predicted performance exceeds or meets regulatory standards, while providing the developer with a comprehensive understanding of predicted disposal system behavior.

A disposal system is composed of many elements, each with unique issues and often dependent upon the other elements. Analysis of each of those elements can be performed with an iterative approach such as that inferred for the entire system. As discussed previously, the use of iteration can guide the analyst to a better understanding of the available information and to those areas where additional information is required. Examples of several key elements of a disposal system are presented below.

SITE SELECTION AND SITE SUITABILITY

Site selection and site suitability determinations are often discussed together because demonstration of suitable site characteristics are required by regulations governing disposal of commercial low-level radioactive waste (3). Certain site characteristics are required for disposal of RCRA hazardous waste. Those characteristics are generally clear and do not require analysis as a basis for the determination of suitability, such as a site is or is not within a mapped 100 year flood plain. Others are relative and can only be determined by and after analysis using performance assessment. Establishing that a site is modelable; capable of being characterized, analyzed, and monitored, is not accomplished without investigation and technical analysis. More important, demonstrating the capability of a site to isolation wastes from the environment requires comprehensive analysis of the disposal system, and quantitative analysis of human exposure to radioactivity based on contaminant transport pathways analysis.

Before a site is selected, the performance assessment process can assist in determining sites acceptable for the isolation of wastes. The quality and quantity of data available at that stage of siting and facility development may be minimal and inadequate to support a full performance assessment demonstrating regulatory compliance. However, the preliminary assessment of performance, based on early definition of source term magnitude and characteristics and preliminary design results, can be used to focus further site characterization efforts and minimize data collection. Focusing further investigation is facilitated by the use of sensitivity analysis incorporating the non-site related features of the waste disposal system. This is an important step in developing an understanding of system performance.

SITE CHARACTERIZATION

The site selection process may guide initial site characterization activities based on minimal or general site data. However, the performance assessment modeling for compliance demonstration will require a detailed and quality assured data set. Performance assessment data requirements are an important input to design of a site characterization program. Existing data should not be ignore, in addition, characterization for the pure joy of characterization should be avoided; that will result in an efficient approach to data analysis. Sensitivity analysis of the preliminary performance assessment can also be useful to determine quantities and quality of the data collected. Quality considerations may for example determine the choice of sampling or analysis techniques. Iteration of the performance assessment seeking a better determination of potential doses may well indicate that new data should be gathered or data quality must be improved.

WASTE INVENTORY AND SOURCE TERM DETERMINATION

At the preliminary performance assessment stage, a simple but reasonable source term approximation may be used. The source term is a combination of characteristics related to radionuclide inventory, waste form, and waste container (4). As the effect of the source term estimate on the predicted performance of the facility is assessed, the level of detail of the source term sub-model may be increased necessitating more and better information on the expected waste and container characteristics and behavior. Inventory characteristics may need to be refined, area where iteration is often required. The result of developing the best possible estimates of inventory may lead to management of the inventory or imposition of special waste acceptance criteria. While waste acceptance criteria are specified for Class A, B and C low-level waste by NRC (5), the DOE specifies that waste acceptance criteria will actually be based on the results of the performance assessment required by Order 5820.2A.

FACILITY DESIGN

The designs of most planned disposal facilities for commercial low-level radioactive waste incorporate engineered barriers to limit contaminant migration. Most of those barriers go far beyond simple layered earthen caps designed to divert water away from the waste limiting leachate production. Many are designed to limit contaminate transport if leachate is produced by off-normal operation of the infiltration limiting barriers. Others are designed to facilitate monitoring, allow retrieval of faulty waste containers, or isolation of sections of a disposal unit to allow for corrective action. Almost all contain concrete barriers and modeling approaches have been developed to address the longevity of concrete (6). Performance management can be used to model and optimize those design features and determine critical design parameters. In addition, performance assessment can help determine the relative role of various design features and, as required by the regulations (5), determine the relative role played by engineered features and by the disposal site. Preliminary performance assessment can be used, even with assumed generic site conditions, for cost/benefit analysis of various designs and design features.

SENSITIVITY AND UNCERTAINTY ANALYSIS

Through the above discussion sensitivity and uncertainty analysis has been mentioned only in passing. These two interrelated activities are critical to performance management. Without a firm grip on the accuracy and precision of the performance assessment results, it is difficult to justify the conclusions. Understanding the sensitivity of the results compared to input values helps determine the required quantity and quality of input data utilized in the performance assessment analysis. During the iterative process of performance management the sensitivity of results compared to the input parameters can be used to prioritize data gathering and data improvement activities.

SUBSYSTEM MODELING

Performance management presents a holistic approach to low-level waste disposal system development, licensing, operation and closure considering the overall performance of the system. In addition, the process of developing information on the system, constructing a conceptual model, developing the mathematical description of the model, "running" the model, and analyzing the results is not limited to the whole system but is essentially applicable to all the component subsystems.

The waste subsystem consisting of the radionuclide inventory distributed among various waste forms and placed in various containers has been treated effectively in this way by Sullivan et al., (4,7). Water coming in contact with the container must breach it and contact the wastes for leaching to take place, after breaching and contact several release mechanisms are possible depending on the radionuclide and the waste form characteristics. Once those processes are aggregated into a conceptual model, mathematical formulations of the processes involved can be written and the resulting relations converted into a computer model to calculate results. Those results may then be interpreted and input into transport models for contaminant transport pathways analysis.

A similar approach can be employed at the site screening stage using existing data and simple models with lenient data input requirements. Models such as those presented by Codell et al., (8) or Kozak et al., (9) require rough approximations of site attributes and general estimates of waste inventory and waste behavior. Used with reasonable first-cut estimates of the input parameters those simple analyses can help prioritize sites for further consideration and point to important data gaps after a site is selected and site characterization is being planned. At this stage some refinements of the original analyses may provide addition confidence in the selected site, and looking forward, help define data requirements and level of detail required for the demonstration of compliance. Use of sensitivity analysis techniques and simple bounding calculations, can provide a basis for defining data quality requirements as input to the site characterization quality assurance plan development process.

RESULTS OF THE PERFORMANCE ASSESSMENT

The results of a performance assessment may result in new efforts to gather more information on site characteristics, expected radionuclide inventory, waste or container characteristics, or changes to the design of the facility. In addition, disqualification of a site may be a result of the iterative process of performance assessment. When the model outputs are considered of adequate quality to approximate the perceived

physical characteristics of a disposal site, to a reasonable degree, the application of those results become more apparent. Many consider the process ended with results of the modeling exercise to establish regulatory standards of performance. Other results may be of greater importance; comparison of the modeling results to regulatory standards is only one of several elements of evidence required to support the issuance of a license for a commercial disposal facility or the finding that a disposal facility can continue to operate in the DOE system.

Waste acceptance criteria are based on results of performance assessment as well as operational health and safety considerations. Waste acceptance criteria are in effect specified for Class A, B and C waste by NRC (5). The basis for waste loadings and stability requirements were developed using performance assessment techniques. The U.S. Department of Energy specifies that waste acceptance criteria are to be based on the results of the performance assessment required by Order 5820.2A.

Operational requirements may be developed based on results of performance assessment, along with placement of different types of waste in the disposal units. For example, intruder waste may be handled by placement of specific wastes at the bottom, or in the interior, of waste disposal units, thus providing reasonable protection from direct contact with that waste. A most effective operational control is limiting total waste inventory of a nuclide or particular nuclides, that option is often overlooked when performance assessments suggest unacceptable results compared to regulatory standards.

Perhaps the most overlooked result of the performance assessment is the development of information required to design an effective post-operational monitoring program (10). Results of performance assessment are important to define pathways and to establish the placement of monitoring points. Those are important to define monitoring criteria for waste constituents, intervals, and duration after closure.

CONCLUSION

The information collected before and the activities required for a performance assessment provide an often overlooked opportunity. The traditional performance assessments focuses on the use of computer codes and analysis to estimate future behavior of a disposal facility based on known information and assumption. Often times more information about the physical characteristics of a site are available than is needed for the modeling effort, or information is not directly applicable to the code used for the modeling effort. And often that information is not considered or integrated into the final analysis for the system as a whole. In addition, the modeling effort is performed after the waste characterization, facility design, and site selection processes have been completed. Using integrated information allows waste management authorities to develop an understanding of the disposal facility as a disposal system. The focus of that understanding is on overall behavior based on all available information at all phases of the disposal system life cycle.

Waste management authorities need all information available to make decisions about long term behavior of waste disposal facilities. The focus of performance assessment has traditionally been on compliance to regulatory requirements. Performance management concepts focus on overall system development and behavior rather than on meeting compliance requirements. Performance assessment methodologies are proven as powerful tools in helping to establish that disposal facilities meet regulatory requirements. Performance management concepts can be a powerful tool to help waste management authorities assess and understand the limits within which a disposal facility can be developed. The iterative process of integrating known information about the disposal site, and results from modeling efforts will enable waste management authorities gain a comprehensive understanding of the overall characteristics of the disposal system.

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