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PERFORMANCE ASSESSMENT FOR FUTURE LOW-LEVEL WASTE DISPOSAL FACILITIES AT ORNL

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1. INTRODUCTION

Until recently, low-level radioactive waste disposal performance assessments within the Department of Energy (DOE) have focused primarily on shallow-land burial with lesser consideration of site characteristics and alternative disposal technologies. The concept of waste disposal by shallow-land burial was based on the notion that a suitable site could be defined and analyzed using methodologies that were predominantly generic. This approach was difficult to apply at Oak Ridge National Laboratory (ORNL) because the potential sites for disposal are in complex geohydrologic settings and a generic methodology does not address many of the relevant site and waste characteristics [1]. An approach to waste management, emphasizing site and waste characteristics, has evolved at ORNL requiring the development of a site-specific performance assessment for ensuring the appropriate protection of public health and the environment.

This paper discusses the strategy for waste management on the Oak Ridge Reservation (ORR) and the approach to preparing future performance assessments that has evolved from previous performance assessment studies of low-level radioactive waste disposal on the ORR. The strategy for waste management is based on the concept that waste classification should be determined by performance assessment rather than the sources of waste. This dose-based strategy for waste classification and management places special importance on the preparation and interpretation of waste disposal performance assessments for selecting appropriate disposal technologies and developing waste acceptance criteria. Additionally, the challenges to be overcome in the preparation of performance assessments are discussed.

2. BACKGROUND

Preliminary performance assessments for radioactive waste disposal facilities on the ORR provided estimates of the doses to an off-site individual and an inadvertent intruder [1]. Several assumptions were necessary in preparing these analyses that were considered to be extremely conservative. The results of the analyses indicate that shallow-land burial or above-grade disposal technologies without engineered features could be associated with potentially significant doses to an off-site individual who uses groundwater or surface water or to an inadvertent intruder. For the ORR, radionuclides of concern include isotopes of Sr-90, Cs-137, Tc-99 and

uranium. Other radionuclides that could exceed the performance objectives of DOE Order 5820.2A [2] for protection of off-site individuals or inadvertent intruders include Eu-152, Eu-154, Am-241, Th-232, Be-10, and Cm-244. As discussed in ref. [1], these radionuclides may not be associated with high doses from disposal once sufficient data are available to justify removing those assumptions that are demonstrated to be unnecessarily conservative. Even with better data, however, the doses attributable to Cs-137, Sr-90, Tc-99, and uranium probably will be of concern in satisfying the performance objectives for wastes generated on the ORR because of the high concentrations present in some wastes.

Generic methodologies for performance assessment are difficult to apply to the ORR because of the extremely complex geohydrologic regime and the diverse wastes generated by DOE operations on the ORR. Adaptations of generic methodologies have been shown to be inappropriate because required input data are not available, reasonable representations of the site are not included in the available models, and waste characteristics affecting disposal facility performance unique to the ORR are not addressed.

With preliminary pathways analyses indicating potential concerns related to public health and the environment with the application of shallow-land burial and tumuli for the disposal of radioactive wastes, a strategy for waste management was needed that would demonstrate appropriate protection of public health and the environment. Since the preliminary performance assessments took no credit for waste form and disposal technology performance, but relied totally on the performance of the site, the identification of waste forms and disposal technologies to complement site performance was suggested. As the strategy evolved, combinations of particular sites, technologies, and types of waste were developed that conceptually addressed the vast majority of radioactive wastes generated on the ORR. The salient feature of this process was the use of dose-based performance objectives to aid in defining the appropriate combinations of site, technology and waste. As a consequence, the strategy is responsive to the capability of the disposal environment on the ORR to accept wastes instead of having the wastes as generated define the wastes to be disposed of on the ORR. Thus, some wastes naturally emerged as being unsuitable for disposal on the ORR. These wastes are to be segregated for storage and disposal at an alternative site or subjected to additional treatment to render them suitable for disposal. With several different types of wastes, sites, and disposal technologies, a waste classification system was developed that formed the core of the waste management strategy on the ORR.

3. ORR WASTE MANAGEMENT STRATEGY

The waste management strategy for the ORR [3] was prepared prior to the issuance of DOE Order 5820.2A; however, the final version of the Order required only minor changes to the strategy. The strategy identifies a "trigger dose" of 10 mrem annual effective dose equivalent to an off-site individual or an intruder as the basis for facility design. This reduced dose level compared to the performance objectives of DOE Order 5820.2A was selected because of the difficulty and uncertainty in predicting site and facility performance. By setting a lower dose for the purposes of design, data gathered during facility monitoring would allow for remedial actions prior to any unanticipated adverse impacts on public health and the environment.

Having defined the limits for protecting public health and the environment, the available sites on the ORR were reviewed [4]. Potential sites on the ORR for waste disposal are of two

types: 1) thick soils and deep aquifers with karst terrain and uncertain geotechnical conditions and 2) thin soils and shallow aquifers with stable geotechnical conditions. The former were considered as potential sites for wastes with low contamination levels at the time of disposal and the latter as potential sites for wastes with higher levels of contamination that would require long-term stability to protect public health and the environment. Given the shallow aquifers at sites with stable conditions, groundwater protection was identified as critical to developing an acceptable waste management system.

Wastes with higher levels of contamination include those subject to radioactive decay (e.g. Sr-90, Cs-137, and Eu-152) and those with long half-lives (uranium and Tc-99). To protect groundwater, wastes subject to decay were considered for isolation using disposal technologies that would limit releases to the environment until the wastes had decayed sufficiently for the trigger dose limit to be satisfied. Wastes with long half-lives were considered for treatment to remove the soluble fraction from the wastes prior to permanent disposal, with intruder protection included in the disposal system to reduce the potential for exposure of inadvertent intruders. This conceptual structure led to the identification of suitable technologies for waste management that were compatible with the available sites for disposal.

Classification of wastes from consideration of the sites, available technologies, and waste characteristics resulted in four classes of radioactive waste for management on the ORR. Each class of waste is associated with concentration limits to be established by performance assessment. Class I waste is composed of slightly contaminated materials that are to be disposed of at sites with deep soils using industrial landfill technology acceptable to the State of Tennessee. Concentration limits would be determined such that an off-site individual or an inadvertent intruder would not receive an annual dose in excess of 10 mrem at any time after the closure of the facility. Class II waste is composed of wastes that would not result in doses to an off-site individual or an inadvertent intruder in excess of 10 mrem at the end of institutional control (active and passive). Class II wastes are largely fission-product wastes that will decay over the period of institutional control and are to be disposed of using tumulus technology with a solidified waste form on sites with stable geotechnical conditions. The facility is to be designed for zero release of contamination and will incorporate monitoring systems to provide early detection of any unforseen releases of contamination from the facility. Class III waste is composed of waste subjected to treatment to remove the soluble fraction of contamination prior to disposal. Following disposal the waste disposal facility would be provided with intruder protection to minimize the potential for inadvertent intrusion. This class of waste is composed largely of uranium wastes. The treatment methods for removing the soluble fraction of the contamination from Class III wastes are under development awaiting a better understanding of the characteristics of wastes included in this waste class. Sites for disposal of Class III wastes have stable geotechnical conditions. Since groundwater would be protected as a result of the waste treatment step, any exposures to off-site individuals would be minimized; however, these wastes are expected to require an intruder protection barrier to limit potential doses from inadvertent intrusion to the performance objective of 10 mrem. Class IV wastes are those wastes requiring further treatment prior to disposal on the ORR as Class I, II, or III wastes, or those to be disposed of at another facility not on the ORR. Off-site alternatives for the disposal of Class IV wastes have not been identified, so these wastes will be stored until an acceptable method for disposal can be developed.

4. PERFORMANCE ASSESSMENT FOR NEW ORR FACILITIES

The strategy for waste disposal on the ORR poses many questions to be addressed and many challenges to be overcome in the preparation of performance assessments for new facilities. The process of selecting sites and technologies for waste disposal has been developed with the intent of using technology to achieve waste treatment and isolation. Previous assessments did not take credit for any improvements in performance resulting from waste form, disposal technology, or waste classification, and waste disposal was addressed in the context of an assumed intruder-homesteader scenario and the assumption that all wastes are subject to transport in groundwater or surface waters. This approach to performance assessment is reasonable for Class I wastes but is not consistent with the waste forms and disposal technologies associated with Class II and Class III wastes. Since performance assessment will be used to define the concentration limits for each waste class as well as in demonstrating compliance with the performance objectives of DOE Order 5820.2A, performance assessment must address the benefits to be derived from using advanced waste forms and disposal technologies. Consequently, valid data are needed for describing waste characteristics, site characteristics, disposal technology performance, and the methodology for performance assessment of engineered systems needs to be considered with care to provide reasonable and defensible results.

Simplistic assumptions and scenarios for the performance of waste forms and disposal technologies tend to negate the potential benefits to be derived from technology improvements. Since improvements in waste form and technology are costly, the commitments of resources associated with their implementation should be justifiable in a performance assessment. Likewise, the methodology for establishing scenarios for intruder behavior should take account of the nature of the waste disposal technology and the waste form. For example, the inadvertent intruder in the intruder-homesteader scenario is assumed to excavate waste in the process of constructing a house and not be capable of distinguishing the native soil from the waste. Following the excavation, the intruder is assumed to grow vegetables and other foodstuffs in contaminated soil. This scenario becomes suspect, for some time period after the loss of active institutional control, as engineered facilities and waste forms are introduced that are not likely to degrade to the extent they are either suitable for excavation or indistinguishable from soil. The inherent acceptance in performance assessment of rapid leachate formation from wastes is also subject to doubt if wastes are treated to remove the soluble fraction prior to disposal. While the presumption that all contamination remaining in the waste after treatment will never be subject to groundwater or surface water transport is also suspect, the proper approach to analysis awaits the development of defensible data to support a performance assessment.

A critical part of preparing a performance assessment is the modeling of the behavior of the disposal site environment. Given the site-specific nature of the waste management strategy and the complex geohydrologic regime of the ORR, the task of modeling site performance becomes much more challenging if the results are to be reasonable representations of the site. Modeling of specific sites requires that the model not only be verified as being mathematically correct but validated as being representative of the site. Validation of site behavior has been addressed [5]. The results emphasize the need for comprehensive data in performance assessment and illustrate the misleading results that could result if generic approaches were applied without site-specific interpretation. Using the experience gained in model validation, performance assessment on the ORR will utilize models that are compatible with the completeness of the

data describing the facility. At this time, many portions of the model structure for each disposal facility are poorly understood, so that simplistic models are being utilized for the purposes of preliminary analysis. The results from these simple analyses are being used to guide the development of additional data describing the system. Noting that performance assessment is a process, the evolution of performance assessment for the ORR supports the notion that performance assessment can guide the implementation of a waste management strategy that protects public health and the environment.

Since the ORR is a complex geohydrologic setting, uncertainties in calculations are likely to be large. A facet of performance assessment yet to be undertaken is the approach towards performing an uncertainty and sensitivity analysis of results. Initial observations suggest that uncertainties in the environmental conditions and the long-term performance of highly engineered facilities will result in large uncertainties in estimated doses to off-site individuals and inadvertent intruders. The expectation is that modeling results and the associated uncertainty analysis will require a substantial degree of interpretation in order to support conclusions that are reasonable and defensible representations of facility performance. For results to be defensible, conservative interpretations are appropriate, but reasonableness necessitates that extremely conservative interpretations be avoided. The emphasis in the interpretation of modeling results will be demonstration of compliance with the performance objectives of DOE Order 5820.2A rather than simulation of the expected performance of the disposal facilities.

5. CONCLUSIONS

Guidance for the preparation of performance assessments has been issued [6,7], but site-specific performance assessments will be difficult to prepare when highly engineered disposal facilities are used in complex environmental settings. Since waste management on the ORR will rely on the proper classification of wastes, performance assessment needs to be performed with the understanding that compliance with DOE Order 5820.2A and justification of the waste classification system for the selected sites, waste and disposal technologies are necessary. To be responsive to these needs, disposal site characterization seeks to identify both the site characteristics that are advantageous and disadvantageous for waste disposal, and waste characterization must address both the needs for modeling and supply sufficient insight to guide technology selection. Wastes not suitable for disposal that may emerge from the performance assessment process will be a subject of special concern. As the characteristics of wastes, sites and disposal technologies are integrated by the performance assessment process, selected disposal technologies will emerge that are defensible on site- and waste-specific bases. For the ORR, which has variable site and waste characteristics, this observation yields a range of technologies identified for waste management that contrasts with the historical practice of using a single technology at a single site for all wastes.

The focus on site-specific analysis on the ORR provides a challenge to preparing defensible performance assessments as well as determining the acceptability of waste disposal at a specific site. The credibility to be attached to any site-specific analysis will be dependent on the validity of the models used for analyzing site performance. The determination of performance assessments that will be both technically adequate and consistent with assessments for other DOE facilities lies ahead, but a sound basis has been developed to proceed with waste

management on the ORR that is protective of public health and the environment in the near term and the long term.

Defensible and reasonable estimates of site behavior and waste form and disposal unit performance for the duration of time that wastes constitute a hazard to human health and the environment are the central challenges for performance assessment on the ORR. As part of this effort, certification of wastes will be critical to ensure that actual operations are representative of predictions. The skill that is demonstrated in forecasting the performance of disposal facilities will largely influence not only the acceptability of waste disposal in the future but also the costs of disposal. Performance assessments that are excessively conservative are certain to yield waste management systems that are unnecessarily expensive. However, assessments that provide best forecasts of performance could yield such an optimistic estimate of facility performance that waste management systems might fail to provide acceptable protection to public health and the environment. Against this challenge of balancing acceptable and affordable waste management systems, the validation of predictive results assumes a new level of significance. The uncertainties associated with providing reasonable estimates of performance for the distant future while striving to comply with fixed performance objectives emphasizes the importance of interpreting results in the formulation of conclusions. Providing reasonable and valid assessments of facility performance will ultimately define the nature of disposal systems in the future.

7. REFERENCES

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