CONF-970537--2

CONTEXT FOR PERFORMANCE ASSESSMENT

D. C. Kocher
Oak Ridge National Laboratory
1060 Commerce Park
Oak Ridge, TN 37830-6480
(423)576-2134

ABSTRACT

In developing its recommendations on performance assessment for disposal of low-level radioactive waste, Scientific Committee 87-3 of the National Council on Radiation Protection and Measurements (NCRP) has considered a number of topics that provide a context for the development of suitable approaches to performance assessment. This paper summarizes the Committee's discussions on these topics, including (1) the definition of low-level waste and its sources and properties, as they affect the variety of wastes that must be considered, (2) fundamental objectives and principles of radioactive waste disposal and their application to low-level waste, (3) current performance objectives for low-level waste disposal in the U.S., with particular emphasis on such unresolved issues of importance to performance assessment as the time frame for compliance, requirements for protection of groundwater and surface water, inclusion of doses from radon, demonstrating compliance with fixed performance objectives using highly uncertain model projections, and application of the principle that releases to the environment should be maintained as low as reasonably achievable (ALARA), (4) the role of active and passive institutional controls over disposal sites, (5) the role of the inadvertent human intruder in low-level waste disposal, (6) model validation and confidence in model outcomes, and (7) the concept of reasonable assurance of compliance.

INTRODUCTION

In developing its recommendations on performance assessment for disposal of low-level radioactive waste, Scientific Committee 87-3 of the National Council on Radiation Protection and Measurements (NCRP) intends to discuss a number of topics that provide a context for the development of suitable approaches to performance assessment. This paper briefly summarizes the Committee's intended discussions on these topics and their importance to performance assessment.

DEFINITION OF LOW-LEVEL WASTE AND SOURCES AND PROPERTIES

In the U.S., low-level waste currently is defined only by exclusion as waste that is not high-level waste, spent fuel, transuranic waste, or uranium or thorium mill tailings, and it arises from many different sources.[1] As a result, low-level waste varies widely in its radionuclide compositions and concentrations and in its physical and chemical forms. The wide variety of low-level wastes is a significant complicating factor in developing suitable approaches to performance assessment, particularly in evaluating releases of radionuclides into the environment. This complication provides one incentive for the increased use of monolithic waste forms (e.g., incorporation of waste into grout), because the performance of such waste forms in controlling releases may be more predictable than the performance of highly heterogeneous, untreated wastes.

FUNDAMENTAL OBJECTIVES AND PRINCIPLES OF WASTE DISPOSAL

A set of fundamental objectives and principles for disposal of radioactive waste has been developed over several decades by international agreement.[2-5] The following points about their application to low-level waste disposal are noted here.

First, current regulations for low-level waste disposal in the U.S.[6,7] are consistent, for the most part, with the fundamental objectives and principles. However, there are some differences. For example, a principle which calls for imposing a constraint on risk (not dose) from disruptive events, including inadvertent human intrusion, presumed unlikely to occur in any year has not been incorporated directly into U.S. regulations.

Second, some of the fundamental principles are not easily applied. For example, a principle which implies that future doses or risks should be given equal weight in determining acceptable disposals, regardless of when they occur, presents conceptual difficulties, and a principle which states that exposures shall be kept as low as reasonably achievable (ALARA) is not easily interpreted,[8,9] as discussed later in this paper:

PERFORMANCE OBJECTIVES FOR LOW-LEVEL WASTE DISPOSAL

Performance objectives for disposal of low-level waste have been established by the Nuclear Regulatory Commission (NRC)[6] and Department of Energy (DOE).[7] These performance objectives have important implications for performance assessment.

First, the performance objectives apply to the overall performance of disposal systems, but performance objectives for individual components of the system, i.e., particular natural or engineered barriers, are not imposed. This approach allows for maximum flexibility in developing appropriate methods of performance assessment for demonstrating compliance with the performance objectives for the total system.

Second, the performance objectives for off-site releases are expressed in terms of constraints on annual dose to individuals. Therefore, performance assessments must calculate maximum concentrations of radionuclides at assumed receptor locations. In addition, time histories of concentrations at these locations normally must be calculated, in order to evaluate the maximum annual dose from all radionuclides combined.

Third, the use of performance objectives expressed in terms of dose means that performance assessments need not consider the probabilities of occurrence of exposure scenarios. Rather, exposure scenarios can be assumed to occur with a probability of unity, provided they are credible for the particular disposal site and facility design.

Although performance objectives for low-level waste disposal are well established, the following important issues about how they should be applied are not yet resolved.

First, an unambiguous policy regarding the time period for applying the performance objectives, or the weight to be given in regulatory decision-making to projected doses at far future times compared with doses at earlier times, has not been developed. Resolution of this issue is important for relatively immobile and long-lived radionuclides and for radionuclides, such as uranium, that decay to radiologically significant long-lived progeny only at far future times.

Second, the performance objectives do not indicate whether they apply to potential doses from exposure to radon. Resolution of this issue is important in determining acceptable near-surface disposals of uranium, thorium, and radium.

Third, a qualitative performance objective for groundwater protection is included in DOE regulations,[7] but its interpretation is ambiguous and such a performance objective is not included in NRC regulations.[6] At DOE sites, the performance objective for groundwater protection usually has been interpreted in terms of compliance with current or proposed standards for radioactivity in public drinking water supplies.[10,11] However, there are many conceptual and practical difficulties with this approach, and it is uncertain whether such requirements also should be applied to surface waters. The establishment of separate performance objectives for protection of groundwater and surface waters could affect acceptable disposals of many radionuclides.

Fourth, determining compliance with fixed numerical performance objectives poses a considerable challenge, given the large uncertainty in any projection of dose. The Committee does not believe that this problem calls for a probabilistic standard, or that a prescribed fraction of calculated doses, taking into account uncertainties in the models and parameter values, must be below a performance objective in order for compliance to be achieved. Rather, the Committee believes that this problem is properly addressed using the concept of reasonable assurance of compliance, as discussed later in this paper.

Finally, the performance objectives call for efforts to maintain releases to the environment as low as reasonably achievable (ALARA). For releases from operating facilities, the ALARA principle often has been implemented by optimizing collective (population) dose using cost-benefit analysis. However, this approach presents a number of conceptual and practical difficulties for waste disposal,[8,9] including (1) the highly uncertain relationship between calculated collective dose and the collective dose that might be experienced at far future times, (2) the need to evaluate temporal and spatial distributions of dose in the population, which places demands on performance assessment different from the modeling approaches normally used in evaluating maximum individual dose, and (3) the arbitrary nature of any assumptions about the temporal and spatial scales for evaluations of collective dose. As an alternative, the Committee believes that evaluations of maximum individual doses and costs for different disposal options would provide a reasonable basis for applying the ALARA principle to low-level waste disposal.

ROLE OF ACTIVE AND PASSIVE INSTITUTIONAL CONTROLS

Active and passive institutional controls, including public records, are expected to be maintained over low-level waste disposal sites for the indefinite future. However, performance assessments often assume that active controls will be maintained for only 100 years and only within about 100 m of a facility, and most performance assessments do not take any credit for the ability of passive controls to limit exposures of off-site individuals or inadvertent intruders beyond the active control period. Particularly at DOE sites, the ability of institutional controls to limit future exposures of the public appears to be a potentially important consideration for performance assessment, because large tracts of contaminated land in the vicinity of permitted low-level waste disposal facilities may never be releaseable for unrestricted use.

ROLE OF INADVERTENT HUMAN INTRUDER

The concept of the inadvertent human intruder plays an important role in determining acceptable near-surface disposals of low-level waste,[6,7] and the Committee intends to discuss this matter in detail. A key point is that inadvertent intrusion should be regarded as an accidental occurrence, and it is not the purpose of assessments of inadvertent intrusion to estimate doses or risks to individuals who might actually intrude onto disposal sites at some time in the future. Rather, the purpose of such assessments is to provide adequate protection of future inadvertent intruders by developing waste acceptance criteria based on pessimistic assumptions about future human activities at disposal sites. In effect, the assumptions about scenarios for inadvertent intrusion usually invoked in performance assessments provide a form of defense-in-depth in protecting members of the public, in the event that active and passive institutional controls over disposal sites would no longer be maintained as intended.

MODEL VALIDATION AND CONFIDENCE IN MODEL OUTCOMES

The concept of model validation, which refers to comparisons of model predictions with relevant data that were not used in developing the model, has been controversial for waste disposal. It is the Committee's opinion that model validation is not a particularly meaningful exercise for performance assessments of low-level waste disposal systems. Rather, the important concern is to develop confidence, or credibility, in the use of assessment models for purposes of regulatory decision-making.

Achieving confidence in the results of performance assessments for regulatory decision-making requires completion of three processes: (1) quality assurance, which involves providing proper documentation and traceability of all data, assumptions, models, and computer codes used in an assessment, (2) model calibration, which refers to fitting a model to represent site-specific conditions, preferably using site-specific data, and (3) evaluation of conservative bias, which refers to the desire, in demonstrating compliance with performance objectives, to select conditions for an assessment that are believed to result in overestimates of actual doses that might be experienced, as a means of compensating for the large uncertainties in predicting actual outcomes.

CONCEPT OF REASONABLE ASSURANCE

The Committee believes that subjective scientific judgment is an essential element of regulatory decision-making for waste disposal systems, primarily because models of the long-term performance of disposal systems cannot be validated, uncertainties in the models used in demonstrations of compliance with regulatory requirements generally are large, and the uncertainties in model evaluations are not amenable to a rigorous and objective quantification. Therefore, unless only trivial disposals of waste are allowed, it generally is not possible to provide absolute assurance of compliance with performance objectives, and the appropriate goal for regulatory acceptance of disposal systems must be a more qualitative and subjective concept of "reasonable assurance" of safety.

As part of its discussion on the concept of reasonable assurance, the Committee intends to present a generally applicable and multi-faceted approach to achieving reasonable assurance of compliance with performance objectives, as summarized in Table 1. For any particular disposal system, some of the factors listed in the table undoubtedly are more important than others. However, some of these factors—including, for example, the use of multiple lines of reasoning, use of judgments in a systematic and properly documented manner, use of well-structured methods of assessment, inclusion of sensitivity and uncertainty analysis, and proper quality assurance and peer review—should be of paramount importance for any site and facility design.

ACKNOWLEDGEMENTS

This work was sponsored by Lockheed Martin Energy Research Corp. under contract DE-AC05-96OR22464 with U.S. Department of Energy, and was supported by the NCRP. Other members of NCRP Scientific Committee 87-3 who contributed to development of this paper include W. E. Kennedy, Jr. (Moeller & Associates, Richland, Washington), M. W. Kozak (QuantiSci, Inc., Denver, Colorado), V. C. Rogers (Rogers & Associates Engineering Corp., Salt Lake City, Utah), R. R. Seitz (International Atomic Energy Agency, Vienna, Austria), T. M. Sullivan (Brookhaven National Laboratory, Upton, New York), and I. White (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

REFERENCES

1. U.S. Department of Energy (DOE), *Integrated Data Base Report—1994: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 11, DOE, Washington, D.C.

2. International Atomic Energy Agency (IAEA), *Safety Principles and Technical Criteria for the Underground Disposal of High Level Radioactive Wastes*, IAEA Safety Series No. 99, IAEA, Vienna, Austria (1989).

3. International Atomic Energy Agency (IAEA), *The Principles of Radioactive Waste Management*, IAEA Safety Series No. 111-F, IAEA, Vienna, Austria (1995).

4. International Commission on Radiological Protection (ICRP), *Radiation Protection Principles for the Disposal of Solid Radioactive Waste*, ICRP Publication 46, *Ann. ICRP* 15, No. 4 (1985).

5. International Commission on Radiological Protection (ICRP), *Protection from Potential Exposure: A Conceptual Framework*, ICRP Publication 64, *Ann. ICRP* 23, No. 1 (1993).

6. U.S. Nuclear Regulatory Commission (NRC), "10 CFR Part 61—Licensing Requirements for Land Disposal of Radioactive Waste," *Fed. Registr.* 47, 57446 (1982).

7. U.S. Department of Energy (DOE), "Management of Low-Level Waste," Chapter III in *Radioactive Waste Management*, DOE Order 5820.2A (1988).

8. National Council on Radiation Protection and Measurements (NCRP), *Principles and Application of Collective Dose in Radiation Protection*, NCRP Report No. 121, NCRP, Bethesda, Maryland (1995).

9. International Atomic Energy Agency (IAEA), "Optimization of Radiation Protection—A Review of Its Application to Radioactive Waste Disposal," Chapter 3 in *Issues in Radioactive Waste Disposal*, IAEA-TECDOC-909, IAEA, Vienna, Austria (1996).

10. U.S. Environmental Protection Agency (EPA), "40 CFR Part 141—National Primary Drinking Water Regulations; Radionuclides," *Fed. Registr.* 41, 28404 (1976).

11. U.S. Environmental Protection Agency (EPA), "40 CFR Part 141—National Primary Drinking Water Regulations; Radionuclides," Proposed Rule, *Fed. Registr.* 56, 33050 (1991).

Table 1. Summary of factors of potential importance in achieving reasonable assurance of compliance with performance objectives for radioactive waste disposal systems

Factor	Description
Multiple lines of reasoning	Consideration of all assumptions, conceptual models, and data bases that are credible and reasonably consistent with available information on performance of disposal system
Use of judgment	Recognition of scientific judgment as an essential element in demonstrations of compliance, and development of assessment approaches that consider judgments in systematic manner
Multiple barriers	Use of multiple and redundant barriers in disposal systems to compensate for uncertainties in evaluating performance of individual barriers and total system
Generic approaches	Use of generic studies to support notion that low-level waste disposal should be safe, and to identify general characteristics of disposal systems that help provide safety
Well-structured methods of assessment	Use of assessment methods structured to help ensure that all credible events and processes affecting performance of disposal system are considered, and that basis for scientific judgments used in assessment is transparent
Modular approach	Use of modular approach in constructing performance assessment models, based on phenomena being modeled, to facilitate descriptions of individual components of disposal system and their interfaces and to permit replacement of subsystem models
Robustness of design and assessment	Incorporation of over-design (safety factors) in disposal systems; use of assessment models that are tolerant to uncertainties in calculational methods (e.g., initial and boundary conditions)
Sensitivity and uncertainty analyses	Determination of parameters or assumptions with greatest effect on model outputs, and investigation of variability in model outputs due to uncertainties in parameters or assumptions; analyses demonstrate understanding of behavior of assessment models

Table is continued on following page.

Table 1. (Continued)

Factor	Description
Different indicators and role of qualitative assessments	Use of safety indicators other than dose or risk (e.g., barrier performance) in making the case for safety; recognition that quantitative results should be complemented by qualitative discussions that provide proper context for interpretation of results and decision-making in the presence of uncertainty
Overall analysis of system safety	Analysis of overall performance of total disposal system (i.e., calculations of dose or risk) to determine attributes of system important to overall safety and required performance of different system components to achieve safety
Iterative approach to assessment	Revisions of assessments as new information on performance of disposal system becomes available, with intent of continuously improving confidence in assessment for regulatory decision-making
Simplicity	Development of equivalent simplified representations of complex models and results that convey essence of assessment, to facilitate communication with regulators and other audiences
Quality assurance and peer review	Systematic and auditable documentation of assessment and development of disposal facility; independent technical appraisal of assessment
Acceptability to different audiences	Tailoring of assessment to different audiences with stake in decisions about acceptability of waste disposals