REVIEW OF ANALYSES BY THE U.S. DEPARTMENT OF ENERGY OF SELECTED TECHNICAL ISSUES IN THE ENVIRONMENTAL PROTECTION AGENCY STANDARDS FOR HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES (40 CFR 191)

Board on Radioactive Waste Management
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Review of Analyses by the U.S. Department of Energy of Selected Technical Issues in Environmental Protection Agency Standards for High-Level and Transuranic Radioactive Wastes (40 CFR 191)

NATIONAL RESEARCH COUNCIL
BOARD ON RADIOACTIVE WASTE MANAGEMENT

Review of Analyses by the U.S. Department of Energy of Selected Technical Issues in Environmental Protection Agency Standards for High-Level and Transuranic Radioactive Wastes (40 CFR 191)

INTRODUCTION

Background

In fulfillment of its responsibility to establish a generally applicable standard for containment of stored high-level and transuranic radioactive wastes, the Environmental Protection Agency (EPA) developed and issued the radioactive waste standard, 40 CFR 191, in 1985. In 1987, the First Circuit Court of Appeals remanded the standard for reasons associated with EPA's treatment of individual and ground water protection. Since that time, EPA has been working on revised standards to satisfy the Court's objections and to take advantage of subsequent technical progress in the understanding of the nature and magnitude of risk from a radioactive waste repository.

The Department of Energy (DOE) is charged with managing and disposing of the nation's high-level and transuranic wastes. The DOE is currently working to establish a repository for transuranic (TRU) wastes at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico, and is investigating the suitability of Yucca Mountain, Nevada, for a repository for both civilian and defense high-level waste. Since the EPA standard was promulgated in 1985, a substantial effort has been made by DOE, its contractors, EPA, and others to improve the understanding of, and ability to analyze, health and environmental risks from such facilities in general and of WIPP and Yucca Mountain in particular. As these analyses have progressed, DOE and EPA have developed an increased understanding of how the radioactive waste standard will influence decisions concerning repositories. DOE and EPA, however, have not agreed on a number of technical and regulatory issues.

In early 1992, DOE and EPA agreed that DOE would provide analyses and other input to EPA on seven issues associated with the standard. At the joint request of the EPA and DOE, the Board on Radioactive Waste Management (BRWM) of The National Research Council (NRC) agreed to review the technical aspects of the DOE analyses of five of these issues. These issues are: (1) Human Intrusion, (2) Uncertainty Propagation, (3) TRU Waste Equivalence Unit, (4) Multi-mode Release Limits, and (5) Collective Dose. The two issues that the BRWM did not review were the "three bucket" approach to treatment of probabilistic analysis and carbon-14. The BRWM was asked to complete its review as quickly as possible to meet the needs of EPA's schedule. The DOE analyses were completed and delivered to EPA on August 10, 1992.

The BRWM conducted its review by holding a workshop on September 23 and 24, 1992 in Washington, D.C. The workshop was attended by a number of invited technical experts, DOE and EPA staff and contractors, and representatives of the State of Nevada and various citizen, environmental and industry groups. Individuals from other organizations with responsibility for oversight of radioactive waste management activities also attended, including representatives from the Nuclear Regulatory Commission, the Nuclear Waste Technical Review Board, the Advisory Committee on Nuclear Waste, and the New Mexico Environmental Evaluation Group.

This review specifically focused on five technical issues and DOE's analysis of them; it does not address the policy aspects of these issues beyond noting differences in the recommendations of the two agencies. The workshop demonstrated that both DOE and EPA approaches to the standard have technical components but are policy driven to a significant extent. The quality of the technical analyses presented to the BRWM varied greatly. In some cases the analysis supported technical improvements to the standards; in other cases the technical analysis appeared to buttress a particular policy conclusion rather than to resolve a technical question.

The workshop described above and the drafting of this report were completed before the National Energy Policy Act of 1992 directed that there be a study by the National Academy of Sciences on the regulation of radioactive waste. This report was not prepared in response to the National Energy Policy Act.

Summary of Findings

Human Intrusion

1. The BRWM agrees with DOE that establishing the probability of human intrusion will be difficult. The BRWM believes that there is a reasonable likelihood of inadvertent human intrusion into any repository over a 10,000-year period. For this reason, the assessment of the risks from human intrusion is more appropriately based on an evaluation of the potential consequences of intrusion than on its probability. The assessment of the potential consequences of human intrusion in comparison to the health objectives of the standard is the most important aspect of the evaluation of human intrusion risk.

Recognizing the difficulty in estimating the probabilities, the BRWM nevertheless believes that useful analysis can and should be done with respect to human intrusion. The BRWM notes the utility of EPA specifying in the standard detailed guidance for dealing with human intrusion scenarios, including the specification of assumptions and parameters.

2. The BRWM finds that DOE's approach would permit releases due to human intrusion up to ten times greater than the limit in the current EPA approach. The BRWM finds that DOE's proposal for the treatment of human intrusion is not technically supported, because of the failure by DOE to demonstrate that the probability of human intrusion is less than 0.1.

3. The DOE has not provided an adequate basis for assuming that the probability of human intrusion is less than one in ten for purposes of determining a given repository's compliance with the standard. The potential health consequences would not necessarily be ten times greater, but would depend on the release scenarios and exposure pathways.

4. The BRWM finds that human intrusion should be a significant factor in site selection. The DOE's approach would reduce the importance of human intrusion as a factor in site selection. Similarly, because the DOE proposes release limits for radionuclides from human intrusion that are ten times the release limits that otherwise apply, the DOE proposal would not encourage the design of disposal systems that are as robust in protecting against the consequences of human intrusion as against other release scenarios.

5. The BRWM finds that the guidance provided by EPA in the draft standard could simplify the analysis of human intrusion.

Uncertainty Propagation

1. Although the BRWM agrees with DOE that uncertainty in repository performance increases with time, the DOE analysis does not support this conclusion. If the standard deviation in releases and individual doses calculated in the DOE analysis were presented in relative rather than absolute terms, as is customary, the uncertainties do not increase with time.

2. The DOE analysis shows little difference in the uncertainty in individual dose versus curies released. No explicit analysis of the comparative uncertainties between individual dose and cumulative release or collective dose was provided. The BRWM considers it possible that individual dose calculations can be either more or less certain than calculations of collective dose.

Transuranic Waste Equivalence Unit

It is clear from the work performed by both EPA and DOE that alternative analytical approaches to waste equivalence exist. There may be a number of reasonable alternatives in calculating the equivalence of different waste types, but the BRWM recognizes that development of some of these approaches may not have progressed to a point where such equivalences can be calculated in a consistent manner. The selection of any particular approach is a policy determination because it defines the acceptable population risk from a TRU repository. It is therefore beyond the scope of this BRWM review. Nevertheless, the BRWM urges continued efforts to select a policy and to develop its associated technically-based waste unit equivalents that would allow general application of the standard to all types of radioactive waste that might go into a repository.

Multi-Mode Release Limits

1. The BRWM agrees with both DOE and EPA that acceptance of the multi-pathway approach could provide a technical improvement over the current single pathway approach, provided that appropriate conservatisms are incorporated into the derivation of pathway release limits to ensure consistency with the health objectives of the standard. The BRWM recommends that multipathway release limits be added to Table 1 of 40 CFR 191.

2. The DOE has proposed an approach that requires some provision for site adjustment factors to allow application of the multi-pathway release limits to a specific repository location. In general, the proposed multi-mode release approach from EPA is simpler than that from DOE in that it would not involve consideration of site-specific factors in its application. If EPA determines that site adjustment

factors are appropriate, it is the BRWM's view that additional work beyond that presented by DOE is needed to develop the methods for deriving those factors.

3. The BRWM did not review the basis for DOE's proposal to remove the containment requirements for carbon-14 and to regulate it as part of the limit on individual exposures. The BRWM notes, however, that if EPA decides to retain containment requirements for carbon-14, it is technically straightforward to do so through an atmospheric pathway release limit.

Collective Dose

1. In the BRWM's opinion, the proposed addition of a collective dose alternative represents a significant improvement in the technical linkage between the overall health protection objectives of the standard and the implementation of the containment requirements. The primary benefits of the release limit table approach is its capacity to reduce the scope of analytical issues considered in licensing. But in some cases, the simplifications necessary in developing release limits for a generic standard may not appropriately represent the situation at a specific site, so that consideration of a site-specific collective dose calculation may be appropriate.

2. In the release limit approach, many simplifying assumptions are made that may not be appropriate for particular pathways at particular sites. If release limits are properly derived, the multi-mode release limits should generally be easier to apply but more conservative than the collective dose alternative. That is, a repository that meets the release limits should also meet the collective dose limit specified in the standard.

3. While it is reasonable to anticipate further technical evolution in the capabilities of performance assessment, it is not reasonable to become unduly prescriptive now about how compliance should be demonstrated within the general framework that the EPA standard provides. The BRWM therefore endorses the proposal by EPA in draft 4 of the standard, also endorsed by DOE, to provide a collective dose alternative for demonstrating compliance with the standard.

4. The BRWM discussed whether the choice between a release limit table or collective dose in a license application should rest with DOE or with the regulator. No consensus was reached on this question, nor on whether this issue falls within the scope of the BRWM's technical review.

Human Intrusion

Statement of the Issue

In evaluating compliance with the containment requirements in the EPA standard, should radioactive releases from inadvertent human intrusion be treated separately from those due to natural processes and events and in a less probabilistic fashion?

Description of the DOE Analysis and Recommendations

The DOE has proposed that radionuclide releases to the accessible environment from human intrusion be treated separately from potential radionuclide releases due to natural processes and events. Under the Department's approach, in any performance assessment of a repository one would assume that intrusion by drilling will occur. The DOE suggests amending the standard to state that a repository be designed to provide a reasonable expectation that cumulative releases of radionuclides to the accessible environment over 10,000 years as a result of drilling not exceed ten times the release limits in Table 1 of 40 CFR 191. Analyzing compliance against ten times the standard reflects the Department's view that the likelihood of releases due to intrusion by drilling would actually be less than one chance in ten for sites subject to the standard.

Under DOE's approach, releases due to human intrusion would be judged against the release limits separately from the analysis of releases due to natural processes and events. In contrast, under the draft EPA standard, the releases due to human intrusion and those due to natural processes and events would be summed and compared against the release limits.

The DOE's recommendation reflects its belief that the current approach to human intrusion is problematic because the probability that human intrusion will occur is difficult to establish, as are the related parameter values in a performance assessment. According to the Department, in predicting natural processes and events one can rely on available geological records; however, no similar analogue exists in the case of human intrusion.

Specific BRWM Questions Considered for the Review

1. How difficult is it to quantify the probabilities of human intrusion versus natural processes and events?

2. Would DOE's proposal provide a level of protection equivalent to that under EPA's draft standard?

3. Is there an adequate technical basis for selecting a probability of 0.1 as an upper bound for human intrusion?

4. What are the implications of DOE's proposal for site selection and repository design?

5. Does EPA provide adequate guidance in assessing human intrusion in the draft standard?

Findings

1. The BRWM agrees with DOE that establishing the probability of human intrusion will be difficult, although it notes that there are natural processes and events that may contribute to releases that may be equally or nearly as difficult to estimate. These include, for example, ground water travel time in a nonuniform aquifer, transport through a fractured unsaturated zone with varying moisture content, and volcanism at certain sites.

In the BRWM's judgment, there is a reasonable likelihood of inadvertent human intrusion into any repository over a 10,000 year period. For this reason, the evaluation of the risks from human intrusion is more appropriately based on an assessment of the potential consequences of intrusion than on its probability. Therefore, the BRWM believes that better understanding of human intrusion risks would result from a systematic consideration of transport pathways and release magnitudes for various intrusion scenarios. The assessment of the potential consequences of human intrusion in comparison to the health objectives of the standard is the most important aspect of the evaluation of human intrusion risk. This recommended approach is like that being taken in the WIPP performance assessment work (SAND91-0893).

Recognizing the difficulty in estimating probabilities, the BRWM nevertheless believes that useful analysis can and should be done with respect to human intrusion. An analysis of the probability of human intrusion can, for example, aid in discriminating among potential repository sites and encourage a greater emphasis on designing disposal systems capable of mitigating the effects of human intrusion.

However, the BRWM notes the utility of EPA specifying in the standard detailed guidance for dealing with human intrusion scenarios, including the specification of assumptions and parameters.

2. The BRWM finds that DOE's approach would permit releases due to human intrusion up to ten times greater than the draft EPA standard. The DOE recommendation that compliance for human intrusion be evaluated against ten times the release limits means that, where the probability of releases due to human intrusion is actually greater than 0.1, releases would be permitted to be ten times above what would be normally allowed under the current draft standard. Additionally, partitioning instead of summing the releases in judging compliance with the EPA limits could result in a decrease in protection versus the draft standard.

3. The BRWM finds that DOE's proposal for the treatment of human intrusion is not technically supported. The DOE has not provided an adequate basis for assuming that the probability of human intrusion is less than one in ten for purposes of determining a given repository's compliance with the standard. If the probability of intrusion were less than 0.1, the Department's proposal would be consistent with the stringency of the current draft standard. But without technical support for assuming that the probability of releases due to intrusion is less than 0.1, the proposal would permit greater releases from human intrusion than from natural processes. The Department did not provide evidentiary support for its assumption in either its written analysis or workshop presentations. The probability of human intrusion may differ substantially from site to site depending upon factors such as the presence of fossil fuel deposits, minerals and potable water. Moreover, the potential health consequences would not necessarily be ten times greater, but would depend on the release scenarios and exposure pathways.

4. The BRWM believes that human intrusion should be a significant factor in site selection. The DOE's approach would reduce the significance of human intrusion as a factor in site selection. By imposing deterministic probability requirements, consideration of human intrusion would likely play a reduced role in the selection of repository sites because compliance determinations would not distinguish the differences in vulnerability to intrusion between sites. Similarly, because the DOE proposes release limits for radionuclides from human intrusion that are ten times the release limits that otherwise apply, the DOE proposal would not encourage the design of disposal systems that are as robust in protecting against the consequences of human intrusion as against other release scenarios.

5. The BRWM finds that the guidance provided by EPA in the draft standard may simplify the analysis of human intrusion. For example, the specification of the number of boreholes per square kilometer and the nature of future states may reduce the complexity of human intrusion analysis. However, EPA should, to the

extent possible, provide a technical justification for such assumptions and require application of alternative assumptions where necessary.

Uncertainty Propagation

Statement of the Issue

In the 1985 EPA standard, the general containment requirements of the standard applied to repository releases over 10,000 years, but the requirements limiting doses to individuals applied for 1,000 years. The failure by EPA to use the same period or to explain why different time periods were applied was one reason why the First Circuit Court of Appeals remanded the standard in 1987. In EPA's draft 4 of the standard, the individual protection requirement is extended to 10,000 years, with an added requirement that calculations extended in time to 100,000 years or until individual doses have reached their peak values, whichever comes first. The ground water protection provision in the draft standard also extends to 10,000 years.

Description of the DOE Analysis and Recommendations

The DOE proposes that the time period for assessments of individual and ground water protection should be no more than 1,000 years after disposal, rather than 10,000 years. This proposal is based on analysis and arguments that the uncertainties that arise when calculations are extended from 1,000 years to 10,000 years and beyond are too great to permit meaningful interpretation of their results. In its submittal to EPA on August 10, the DOE provided analyses indicating that uncertainty grows dramatically as the period of assessment is extended. The DOE contractors performed calculations for both releases and individual doses from three long-lived radionuclides, and propagated uncertainties for a period of 100,000 years. In this analysis, standard deviations were estimated and compared at 1,000, 10,000 and 100,000 years. The conclusion based on these analyses was that uncertainties increase by many orders of magnitude over this period. In the presentation of this analysis to the BRWM, the DOE contractor concluded that "release calculations at 100,000 years are more uncertain than at 10,000 years; adding increased complexity to the model and more nuclides will increase uncertainty; and dose calculations beyond 1,000 years (at 10,000 years) are uncertain to the point of being highly questionable" (from J. Duguid's presentation at the BRWM's September 23-24, 1992 Workshop on EPA's 40 CFR 191).

Specific EPA Questions Considered by the BRWM

EPA asked the BRWM to consider the following questions related to the problem of uncertainty propagation:

1. Is the DOE assessment a complete and technically correct evaluation of the uncertainties involved?

2. Is the uncertainty associated with assessment of individual dose for undisturbed performance over 10,000 years different from the uncertainty associated with assessment in population dose for disturbed performance over 10,000 years?

Findings

1. Although the BRWM agrees with DOE that uncertainty in repository performance increases with time, the DOE analysis does not support this conclusion. The DOE analysis provides calculations of the standard deviation (σ) in releases and individual doses from technetium-99, iodine-129, and neptunium-237. The calculated standard deviations do increase significantly with time. One reason for the large increase in the absolute value of the standard deviation from 1,000 years to 10,000 years in the DOE calculation is that the expected ground water travel time from the repository to the accessible environment, i.e., the mean travel time for the range employed in simulations, exceeds 1,000 years. In the case of neptunium-237, even the minimum travel time for the range employed exceeds 1,000 years. Thus, the calculated release and its uncertainty are near zero at 1,000 years. Once the minimum ground water travel time to the accessible environment has been reached, both the calculated releases and their associated uncertainties will begin to increase.

The appearance of increasing uncertainty in the DOE analysis comes from the use of an absolute measure for uncertainty. However, it is customary to express the uncertainty on a relative rather than on an absolute basis, and usually in terms of a multiplicative factor around the mean (μ), for the projection of the performance of radioactive waste repositories and for other issues where the analyst is led to use logarithm-based distributions and expressions of results. In such cases, when one reports that an estimate is μ, to within a factor of 3, what is meant is that the likely result lies between $\mu/3$ and 3μ. In this case the factor "3" is the measure of uncertainty. Thus, if the standard deviations are presented normalized to means, that is, as the ratio of σ to μ, the uncertainties do not increase with time. On this basis, the DOE analysis does not demonstrate increasing uncertainty.

While it is the BRWM's view that the DOE analysis did not demonstrate increasing uncertainty with time, it is likely that the uncertainty does increase. The DOE analysis employed no time-varying analytical factors; it assumed that neither the models nor the parameters change with time. The DOE report noted that there may be features that change with time and that "Merely extrapolating the present conditions is not a defensible way to extend performance assessment calculations over long periods of time" but it did not attempt to quantify the effects of such factors (Chapter 8 of the August 10, 1992 DOE report, page 8-5).

2. The DOE analysis shows little difference in the uncertainty in individual dose versus curies released. No explicit analysis of the comparative uncertainties between individual dose and cumulative release or collective dose was provided. The BRWM considers it possible that individual dose calculations can be either more or less certain than calculations of collective dose. For example, if releases from a repository are largely limited by the solubility of particular radionuclides, as could be the case for plutonium, then it is likely that individuals drinking water drawn from wells near the site could be exposed to concentrations at the solubility limit. In such a case, the uncertainty in individual dose may be lower than the uncertainty in collective dose, since the collective dose calculation would depend on uncertainties in the flow rate of ground water that would not contribute to uncertainty in individual dose. Conversely, if collective dose is proportional to the quantity of radioactive material released, and releases are determined by a leaching rate, then the uncertainty in collective dose may be comparatively low.

TRU Waste Equivalence Unit

Statement of the Issue

The issue of waste unit equivalence centers around the problem of consistently applying 40 CFR 191 to different radioactive waste forms. In particular, there is no generally accepted "waste unit" that assures consistent and equivalent treatment of different forms of radioactive waste under 40 CFR 191.

Description of the DOE Analysis and Recommendations

The DOE's position is that the use of values in the 1985 version of 40 CFR 191 that equate a quantity of transuranic (TRU) waste with quantities of high-level waste (HLW) and spent nuclear fuel (SF) is not technically sound. The DOE argues that military TRU waste is not associated with commercial reactor fuel, does not have a unit comparable to a metric ton of heavy metal (MTHM) of fuel, and does not have a comparable risk/benefit relationship.

The DOE's preferred approach would be the establishment of an absolute TRU fundamental criterion based on acceptable risk to the populace. The specific proposal is to allow the risk from a 20 million curie (MCi) TRU repository to equal that from a 100,000 MTHM HLW repository. The DOE proposal would result in revising the EPA standard's TRU equivalent from 1 MCi TRU per 1000 MTHM to 0.2 MCi per 1000 MTHM. This would relax the requirements for TRU waste by a factor of 5 in comparison with the current EPA standard.

EPA'S Comments and Approach

The EPA takes the position stated in the preamble to the 12/29/82 proposed rule, that radioactivity from either high-level or TRU wastes should be "isolated with about the same degree of effectiveness." However, EPA indicated that it is reexamining the basis for the waste unit in response to comments received on recent working drafts of 40 CFR 191. EPA agreed that "complete equivalence" would require some minor changes to the rule. The change currently proposed by EPA involves a time integration of the waste activity level and the adoption of a "risk factors" formula. Analyses presented at the workshop by an EPA contractor on the methodology for deriving equivalence factors and by the Environmental Evaluation Group (EEG) indicated that this condition of equivalent effectiveness would result in changing the TRU equivalence to 3-10 MCi per 1000 MTHM. This change would incorporate a time-averaging of risks, and is consistent with EPA's original stated objectives. EPA indicated that an additional benefit of this single formula approach is that it is flexible enough to be used for TRU waste and any other waste stream that may be disposed of in a HLW repository, e.g., various types of greater-than-class-C wastes.

Findings

The work performed by both EPA and DOE clarify the existence of alternative analytical approaches to waste equivalence. There may be a number of reasonable alternatives to calculate the equivalence of different waste types, but the BRWM recognizes that development of some of these approaches may not have progressed to a point where such equivalences can be calculated in a consistent manner. The selection of any particular approach, or definition of a TRU unit of equivalence, is a policy determination because it defines the acceptable population risk from a TRU repository. It is therefore beyond the scope of this BRWM review. Nevertheless, the BRWM urges continued efforts to select a policy, and to develop its associated technically-based waste unit equivalents that would allow general application of the standard to all types of radioactive waste that might go into a repository.

Multi-Mode Release Limits

Statement of the Issue

A central component of the EPA standard is its containment requirements. The purpose of these requirements is to restrict releases of radioactive materials from the repository in order to limit exposures of populations to radiation to a level that would lead to less than 1,000 deaths in 10,000 years. Other provisions of the standard set limits on individual exposures. Until draft 4 of the standard was released by EPA in February 1992, the containment requirements were implemented through Table 1 of Appendix A, which provided release limits, in terms of curies per 1,000 MTHM, for each isotope likely to be found in a repository. The calculations behind the current table are based on exposures that would occur if wastes moved into a river at the boundary of the accessible environment, defined by EPA to be 5 km from the repository. (The value for carbon-14 in the table is an exception; it was derived based on a volcanic release). At issue is whether and how this table should be modified to consider multiple pathways through which exposures could occur.

The BRWM was asked to consider whether utilization of different multiple path release limits was appropriate for representing compliance with the objectives of the proposed standard. A related issue is the proposal in draft 4, discussed in more detail in the following section of this report on collective dose, to permit compliance with the containment requirements either through use of a release limit table or through a calculation of collective dose.

If the multi-path release concept is to be adopted, several specific items require determination, including:

1. Should multi-path release limits replace the single release limit Table 1 of the proposed standard or be considered as an option?

2. Are specific site adjustment factors necessary and should they be included in the standard? If so, how should they be derived?

3. Should an atmospheric release pathway be included?

Description of the DOE Analysis and Recommendations

The DOE asserts that the single table of release limits may be inappropriate because it is based on a release to a large river immediately adjacent to the repository boundary whether or not such a river exists. The DOE advocates the addition of a multiple pathway table of release limits to account for release paths

via land, well water, rivers and oceans, but recommends leaving gaseous releases to be considered as Individual Protection Requirements.

Utilization of the multi-pathway approaches, in accord with the DOE recommendation, also includes site adjustment factors (or site-specific characteristics) to permit determination of releases at the actual likely point at which radioactive materials enter a river or well, rather than calculating discharges at the repository site boundary as does the current Table 1. To illustrate the type of site adjustment recommended, the DOE proposes that attenuation in releases between the defined accessible environment and a nearby river would be estimated and used as an adjustment in considering whether the release limit was met. Additional site adjustment factors are proposed to account for the fact that water upstream from where wastes would enter a river would not be contaminated.

EPA'S Approach

At the workshop, the EPA staff presented their proposed approach which is quite similar to that proposed by the DOE. The EPA agrees with the comment that the multi-pathway approach can be effective in treating generic sites, including those that would not conform to the present single pathway approach. The EPA proposes to add release limits for ground water, land surface, and violent gaseous releases to the current table based on a surface water release limit. For any particular site, pathways would be considered or not on the basis of whether the particular release mode was expected to occur. For example, EPA would not require consideration of a river pathway for sites that are not near a river.

EPA's proposed approach would eliminate the ocean pathway, but would include one for gaseous releases due to violent interactions (e.g., volcanoes). The proposed release limits for the land surface and surface water pathways appear to be the same as that of the DOE, although there are differences in the proposed methods for application due to the site adjustment factors recommended by the DOE. The proposed well water release limit was based on drinking water exposures only; it did not consider food chain exposures that might result from the use of well water for irrigation.

Findings

1. The BRWM agrees with both DOE and EPA that acceptance of the multi-pathway approach could provide an appropriate alternative to the current single pathway approach, and recommends that multi-pathway release limits be added to Table 1. This is provided that appropriate conservatisms are incorporated into the derivation of the release limits to ensure consistency with the health objectives of the standard, especially in light of the many simplifying assumptions that go into

repository that meets the release limits should also meet the collective dose limit specified in the standard.

3. In its 1990 report, *Rethinking High-Level Radioactive Waste Disposal*, the BRWM noted that our understanding of the performance of a repository and technical capability to assess its performance are advancing. Because the radioactive waste standard has never been implemented, there are also significant uncertainties in the standard of proof required for its satisfaction and in what constitutes sufficient evidence that compliance has been demonstrated. In *Rethinking High-Level Radioactive Waste Disposal*, the BRWM recommended that the appropriate management approach to these circumstances was to maintain flexibility, to adjust the program iteratively in response to new understandings and information, and to understand that under these conditions, there is value in delaying those decisions that can be reasonably delayed until more is known. Given that it is reasonable to anticipate further technical evolution in the capabilities of performance assessment, it is not reasonable to become unduly prescriptive now about how compliance should be demonstrated within the general framework that the EPA standard provides. The BRWM therefore endorses the proposal by EPA in draft 4 of the standard, also endorsed by DOE, to provide a collective dose alternative for demonstrating compliance with the standard.

4. The BRWM discussed whether the choice between a release limit table or collective dose in a license application should rest with DOE or with the regulator. No consensus was reached on this question, nor on whether this issue falls within the scope of the BRWM's technical review.

References

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