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AN SAB ADVISORY: Modeling of Radionuclide Releases from Disposal of Low Activity Mixed Waste

ADVISORY ON THE OFFICE OF RADIATION AND INDOOR AIR'S DRAFT PROPOSALS ON MODELING OF RADIONUCLIDE RELEASES FROM DISPOSAL OF LOW ACTIVITY MIXED WASTE BY THE RADIATION ADVISORY COMMITTEE

February 22, 1999

EPA-SAB-RAC-ADV-99-006

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M. Street, S.W.
Washington, DC 20460

Re: Advisory on Modeling of Radionuclide Releases from Disposal of Low Activity Mixed Waste (LAMW)

Dear Ms. Browner:

The enclosed Advisory was developed by the Radiation Advisory Committee (RAC) of the Science Advisory Board (SAB) in response to a request from the Office of Radiation and Indoor Air (ORIA) to provide advice on the modeling of low activity mixed radioactive waste (LAMRW) and specifically to respond to a three element Charge, summarized below (the detailed Charge may be found in Section 2.2 of the enclosed report:

a) Does the EPA dose assessment reasonably cover the range of hydrogeologic and climatic settings that might be used for disposal of low-activity mixed waste?

b) What modeling time frame does the Committee recommend be used to project potential doses from disposal of low-activity mixed waste? Does a 1000-year time frame provide an adequate technical basis for setting regulatory limits?

c) Is it reasonable to assign a "high" release rate for the duration of the simulation? Does the SAB advise an alternative approach?

The RAC held a public meeting on November 17, 18, and 19, 1998 at which it was briefed by, and had technical discussions, with ORIA staff, as well as a writing session by the Committee. A public teleconference was also held on December 15, 1998. The advisory generated by this meeting responds both to the three Charge questions, as well as addressing other issues identified during the public meeting.

ORIA conducted analyses for three sites, based on the hydrogeologic and climatic characteristics of well-characterized Department of Energy (DOE) sites selected from a group of ten such sites analyzed in a screening study. The Committee concluded that these sites do not necessarily cover the range of conditions that might be encountered at current or future RCRA-C facilities. For example, they include no sites outside the conterminous United States, and probably do not cover the range of possibilities for depth to groundwater, existence of snowpack and freeze-thaw cycles, or soil composition in which RCRA-C facilities are or could be sited. Moreover, the modeling as conducted does not consider such other site characteristics as soil and waste pH, redox conditions, the presence of reactive organic matter, and biological activity. The Committee recommends that ORIA conduct at least screening analyses of the extent to which these factors could affect radionuclide migration rates. Furthermore, Charge a), as framed by ORIA seems overly narrow. Although it is desirable to select sites to bound important potential site conditions and characteristics, the ultimate goal should be to bound probable site *performance*. ORIA should consider enhancing its approach to include additional site characteristics.

The Committee concluded that a sensitivity analysis of the modeling time frame could provide potentially useful information on the variation of peak dose with time horizon, especially for less mobile radionuclides with long half-lives. The Committee did not reach consensus, however, on how ORIA should weigh projections for the longer periods against the more reliable projections for shorter periods. All members agreed that under the modeling assumptions used by ORIA, peak doses for some radionuclides might occur after 1,000 years and be significantly higher than at 1,000 years. While some members stated that this scientific conclusion was sufficient to extend the modeling time frame to 10,000 years or beyond, others emphasized that uncertainties inherent not only in the modeling assumptions but also about future scientific and social changes could make the results irrelevant. Consequently, the Committee's advice is limited to suggesting issues that should be considered in ORIA's eventual decisions about LAMW. Among them are:

a) Characterization of the candidate wastes with respect to concentrations and total inventories of long-lived radionuclides,

b) Harmonization of the modeling time frame between radioactive and hazardous wastes,

c) Consideration of uncertainties about not only the validity of the technical assumptions but also in the relevant medical and social conditions far in the future,

d) Consideration of issues about site ownership, and

e) Appropriate degree of conservatism given the policy intent of the proposed LAMW disposal option.

The Committee believes that changes in assumptions about the time course of concrete degradation might significantly affect predictions of the time to peak dose or its magnitude. The assumption of a constant rate of release relative to the remaining inventory of a radionuclide could either overestimate or underestimate peak dose, depending on the half life of the parent radionuclide and the characteristics of its progeny. The Committee recommends that a simulation be performed to verify, at least qualitatively, that the constant loss rate assumption is reasonably--but not excessively--conservative. Other assumptions, such as an exponential deterioration model, could also be considered, although selection of a technically defensible deterioration rate could be problematic because it could be a complicated function of physical, geochemical, and thermal factors.

The Committee's major findings and recommendations concerning those issues not included in the Charge include:

a) ORIA should better justify the choice of the PRESTO model as the principal tool for the analysis. Benchmarking of the model through comparison with other models of similar intent would be useful, as would demonstration that its scope of applicability is appropriate.

b) ORIA should consider using a classification of radionuclides according to half-life as a refinement of the "unity rule" for determining the acceptability of wastes with more than one important radionuclide.

c) ORIA should consider whether the total quantity of waste to be emplaced in a RCRA-C facilities, not just its radionuclide concentrations, should be part of the decision process. Moreover, the potential presence of non-stabilized hazardous wastes in a solid waste management unit (SWMU) near to LAMW RCRA-C SWMUs should be considered.

d) Various modeling assumptions should be re-examined, including ones about segregated vs. random emplacement, the amount of waste potentially subject to disposal as LAMW, the composition of such wastes, and the classification of radionuclides as mobile or immobile.

e) Given the wide range of environments that might be found at current or future RCRA-C sites, ORIA might be well advised to propose two sets of concentration criteria, one valid for relatively dry sites with deep groundwater and another for wet sites. The latter might be able to accept only wastes with short-lived radionuclides.

f) The modeling effort may be an opportunity for EPA to examine the similarities and differences in radioactive waste and hazardous waste control systems and waste acceptance criteria and to harmonize them to the extent feasible. Additional classes of waste could also be analyzed within the modeling structure.

g) ORIA should take care not to create an incentive for a generator to produce a waste classifiable as LAMW that would otherwise be simply Low-Level Radioactive Waste (LLRW). It should also examine whether redefining the waste would change the liability distribution between waste generators and disposal facility operators.

The RAC appreciates the opportunity to provide this advisory to you and we hope that it will be helpful. We look forward to the response of the Assistant Administrator for Air and Radiation to the advisory in general and to the specific comments and recommendations in this letter in particular.

Sincerely,

/signed/
Dr. Joan M. Daisey, Chair
Science Advisory Board

/signed/
Dr. Stephen L. Brown, Chair
Radiation Advisory Committee

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This report has been written as part of the activities of the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute a recommendation for use.

ABSTRACT

On November 17-19, 1998, the Science Advisory Board's Radiation Advisory Committee conducted an advisory of the Office of Radiation and Indoor Air's (ORIA) modeling of low activity mixed waste, including: dose assessment over a wide range of disposal site-specific hydrogeologic and climatic settings; the 1000 year modeling time frame; and using a "high" release rate from concrete for the modeling.

The Committee found that the sites modeled do not necessarily cover the range of conditions that might be encountered at RCRA-C facilities. It recommends that ORIA should further assess the impact of site-specific conditions to bound probable site performance better. While the Committee did not reach consensus on the modeling time frame, it recommends that ORIA consider: conducting a sensitivity analysis to address the variation of peak dose with time; improving its waste characterization; the relationship between radioactive and hazardous waste modeling time frames; uncertainties in its technical assumptions and future medical and social conditions; site ownership; and its degree of conservatism given the intent of the proposal. The Committee recommends that ORIA perform a simulation to verify that its assumptions about the releases from concrete are reasonably conservative.

Beyond the Charge, the Committee recommends that ORIA: better justify choosing the PRESTO model; consider classifying radionuclides according to half-life; consider whether the total quantity of waste as well as its radionuclide concentrations should be part of the decision process; re-examine certain modeling assumptions; propose concentration criteria addressing "dry" and "wet" sites; and compare control systems and acceptance criteria for radioactive and hazardous wastes.

KEY WORDS: low activity mixed wastes; hazardous waste facilities; Resource Conservation and Recovery Act, Subtitle C (RCRA-C); low level radioactive waste; modeling of potential releases of radionuclides.

U.S. ENVIRONMENTAL PROTECTION AGENCY
SCIENCE ADVISORY BOARD
RADIATION ADVISORY COMMITTEE
November 17-19, 1998, and December 15, 1998

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1. EXECUTIVE SUMMARY

The Office of Radiation and Indoor Air (ORIA) is considering a proposal to allow certain commercial low activity mixed wastes (LAMW) to be disposed of in facilities permitted as hazardous waste facilities under the Resource Conservation and Recovery Act, Subtitle C (RCRA-C). LAMW is waste that is currently classified as hazardous under RCRA and as radioactive waste under the Atomic Energy Act (AEA). Only a subset of the waste classified as Class A low level radioactive waste (LLRW) would qualify, and the RCRA-C facility would have to obtain a (presumably simplified) license for radioactive waste from the Nuclear Regulatory Commission or an Agreement State.

In support of its decision, ORIA is conducting modeling of potential releases of radionuclides from such wastes to establish radionuclide concentration criteria for waste acceptance. Before proceeding further, ORIA sought advice from the Science Advisory Board's (SAB) Radiation Advisory Committee (RAC) on three questions regarding modeling procedures and assumptions. The Committee's advice on these questions and on some related broader issues is summarized below.

Charge question (a) asked:
Having relied on extensive site characterization data from existing and potential low-level radioactive waste disposal landfills, does the EPA dose assessment reasonably cover the range of hydrogeologic and climatic settings that might be used for disposal of low-activity mixed waste?

ORIA conducted analyses for three sites based on the hydrogeologic and climatic characteristics of well-characterized Department of Energy (DOE) sites selected from a group of ten such sites analyzed in a screening study. The Committee concluded that these sites do not necessarily cover the range of conditions that might be encountered at current or future RCRA-C facilities. For example, they include no sites outside the conterminous United States, and probably do not cover the range of possibilities for depth to groundwater, existence of snowpack and freeze-thaw cycles, or soil composition in which RCRA-C facilities are or could be sited. Moreover, the modeling as conducted does not consider the effects of such other site characteristics, such as soil and waste pH, redox conditions, the presence of reactive organic matter, and biological activity. The Committee recommends that ORIA take a broader look at the range of radionuclide leaching and transport behaviors that might occur at real RCRA-C sites. Furthermore, Question a), as framed by ORIA, seems overly narrow. While it is desirable to select sites to bound important potential site conditions and characteristics, the ultimate goal should be to bound probable site *performance*. Based on the approach being taken, it may be difficult to develop predictions of the long-term performance of a mixed waste disposal site. ORIA should also consider using more comprehensive decision schemes such as Total Systems Performance Assessment. However, the Committee is not recommending that the modeling exercise include site characteristics that would clearly be found unacceptable for future RCRA-C facilities.

Charge question (b) asked:
What modeling time frame does the Committee recommend be used to project potential doses from disposal of low-activity mixed waste? Does a 1000-year time frame provide an adequate technical basis for setting regulatory limits?

The Committee concluded that a sensitivity analysis of the modeling time frame could provide potentially useful information on the variation of peak dose with time horizon, especially for less mobile radionuclides with long half-lives. The Committee did not reach consensus, however, on how ORIA should weigh projections for the longer periods against the more reliable projections for shorter periods. All members agreed that under the modeling assumptions used by ORIA, peak doses for some radionuclides might occur after 1,000 years and be significantly higher than at 1,000 years. While some members stated that this scientific conclusion was sufficient to extend the modeling time frame to 10,000 years or beyond, others emphasized that there are uncertainties not only in the modeling assumptions but also about future scientific and social changes that could make the modeling results irrelevant. Consequently, the Committee's advice is limited to suggesting issues that should be considered in ORIA's eventual decision. The issues fall into four categories: scientific, future land use, public acceptance, and economic viability, and are explained in detail in Section 3. Major considerations include the following items:

a) ORIA should attempt to characterize the wastes that might fall under the proposed disposal option. If these wastes rarely contain long-lived radionuclides, then a shorter modeling time frame is more easily supported, while a substantial complement of long-lived radionuclides would argue for a longer time frame or a constraint on the waste to prevent disposal of such radionuclides.

b) ORIA and other offices of EPA should consider the issue of harmonizing the time horizons used in analyzing the risks of radionuclides and hazardous wastes. For instance, lead has an infinite half life and has many other characteristics in common with long-lived radionuclides.

c) Uncertainties about not only radionuclide releases and pathways of exposure but also medical and social conditions grow greatly as the modeling time frame is extended. Does modeling to 1,000 or 10,000 years help or hinder public acceptance of the results?

d) The requirements for site ownership differ between radioactive waste disposal and hazardous waste disposal, with radioactive wastes being more likely to remain under government control. Should this difference argue for a longer modeling time frame, consistent with other analyses of radioactive waste?

e) The proposed alternative for LAMW disposal will be useful to waste generators only to the extent that they can dispose of waste less expensively and/or more easily than under current regulations. Excessive conservatism in modeling assumptions, including the time frame, may exclude most waste from the proposed disposal option. On the other hand, if modeling to 1,000 years or less does not convince the public to accept radioactive wastes into RCRA-C facilities, the contemplated rulemaking will also be in vain.

Charge question (c) asked:
Given the modeling approach described [in the Agency's presentation], and the available knowledge regarding concrete durability and modes of degradation, is it reasonable to assign a "high" release rate for the duration of the simulation? Does the SAB advise an alternative approach, such as assuming a lower release at the start and increasing it incrementally over the modeling period, thereby mimicking the gradual deterioration of the concrete?

The Committee believes that changes in assumptions about the time course of concrete degradation might significantly affect predictions of the time to peak dose or its magnitude. The assumption of a constant rate of release relative to the remaining inventory of a Radionuclide, even when its quantity and half-life are taken into consideration, could either overestimate or underestimate peak dose, depending on the half life of the parent radionuclide and the characteristics of its progeny. The Committee recommends that a simulation be performed to verify, at least qualitatively, that the constant loss rate assumption is reasonably--but not excessively--conservative. Other assumptions, such as an exponential deterioration model, could also be considered. The Committee recognizes that selection of a technically defensible deterioration rate could be problematic because it could be a complicated function of physical, geochemical, and thermal factors. The Committee also notes that the concrete deterioration assumptions interact with the containment failure assumptions; the timing of water infiltration through the cap and leakage through the liners could affect the rate of concrete deterioration as well as its significance. Finally, ORIA should consider how to deal with wastes that are not ordinarily disposed of in concrete containment. Will such wastes simply be excluded from consideration under the contemplated rule? If not, are the assumptions about concrete degradation conservative in comparison with the expected behavior of the actual containment?

During the public meetings, the Committee identified and discussed several issues not incorporated in the Charge; these issues are discussed below.

The Committee reached some conclusions and related recommendations about the LAMW modeling approach that go beyond the original three questions of the Charge. They include comments on the overall modeling structure as well as science policy and environmental policy questions.

The Committee believes that ORIA should better justify the choice of the PRESTO model as the principal tool for the analysis. Benchmarking of the model through comparison with other models of similar intent would be useful, as would demonstration that its scope of applicability is appropriate.

ORIA should consider using a classification of radionuclides according to half-life as a refinement of the “unity rule” for determining the acceptability of wastes with more than one important radionuclide. Otherwise, radionuclides with vastly different times of peak dose may be inappropriately combined.

As currently structured, the decision criteria for waste acceptance appear to be based only on concentration. ORIA should consider whether the total quantity of waste to be emplaced in RCRA-C facilities should also be part of the decision process. Moreover, the potential presence of non-stabilized hazardous wastes in a solid waste management unit (SWMU) near-to the RCRA-C facilities should be considered, as they may affect the stability of the concrete containment or the mobility of some radionuclides.

Various modeling assumptions should be re-examined, including ones about segregated vs. random[4] emplacement, the amount of waste potentially subject to disposal as LAMW, the composition of such wastes, and the classification of radionuclides as mobile or immobile. In addition, the time-step modeling must be based on rigorously random, stratified sampling, with attention devoted to choosing modeling time steps that are appropriate to the dynamics of radionuclide decay, concrete degradation, and waste movement.

Given the wide range of environments that might be found at current or future RCRA-C sites, ORIA might be well advised to propose two sets of concentration criteria, addressing the interaction of waste and site. One set could be designed to be valid for relatively dry sites with deep groundwater and the other for wet sites. The latter sites might be able to accept only wastes with short-lived radionuclides.

The Committee sees this modeling effort as an opportunity for EPA to examine the similarities and differences in radioactive waste and hazardous waste control systems and to harmonize them to the extent feasible. At the same time, ORIA could study, within the same modeling framework, a range of waste types beyond that currently being considered, for example wastes containing RCRA hazardous and technologically enhanced naturally occurring radioactive material (TENORM) radioactive constituents. ORIA could also study harmonization of the still-to-be-determined “reference doses” with risk criteria used for hazardous chemical wastes.

Because a waste that contains both chemical and radioactive constituents is potentially more hazardous than one that contains only one or the other (at the same concentrations), and

[4] By "random," ORIA means emplacement that is not limited to a particular portion of the RCRA-C cell. No formal randomization process is implied.

because the cost of disposal for hazardous wastes is usually less than for radioactive wastes, ORIA should take care not to create an incentive for a generator to classify improperly a waste as LAMW that would otherwise be simply LLRW. It should also examine whether redefining the waste would change the liability distribution between waste generators and disposal facility operators.

2. INTRODUCTION

2.1 Background

When a waste is designated as both "hazardous" because of its chemical or physical properties and "radioactive" because of the presence of radionuclides--a "mixed waste"-- the options for its disposal are limited under current regulatory requirements promulgated by the U.S. Environmental Protection Agency (EPA or "the Agency") under the Resource Conservation and Recovery Act (RCRA) and by the U.S. Nuclear Regulatory Commission (NRC) under the Atomic Energy Act (AEA), respectively. Although certain mixed wastes can be disposed at a commercial facility in Utah, and although Federal or State regulatory agencies may allow disposal of certain types of mixed wastes elsewhere under special circumstances; finding a disposal alternative at a tolerable cost is often difficult, particularly for small-volume generators such as universities, medical facilities, and other research laboratories. The EPA is therefore seeking alternatives that would facilitate the safe disposal of these wastes.

As a start, the Agency is investigating the merits of a regulation that would permit certain low-activity radioactive mixed wastes (LAMW) to be disposed of in facilities permitted as hazardous waste facilities under RCRA Subtitle C (RCRA-C). Such a site would be required to obtain a radioactive waste license under NRC (or agreement state) jurisdiction. The intent of the initiative is to encourage simplification of the radioactive materials license requirements for RCRA-C sites willing to accept LAMW that meet specific dose criteria considered protective of human health and the environment. The contemplated regulation would establish acceptance criteria, generally stated as concentrations of specific radionuclides in the waste, that if met would allow the disposal of the mixed waste in a RCRA-C facility.

EPA's Office of Radiation and Indoor Air (ORIA) is currently conducting a modeling exercise to determine what those criteria might be in order to meet radiation dose limits yet to be finalized. To conduct that modeling, ORIA needs to make a number of assumptions about how the radionuclides might be released and how people living near or even on the site might become exposed to them. It also needs to set limits on the range of possible conditions that it will include in the modeling of human health risks. Using overly conservative assumptions and procedures or an extremely low reference dose might vastly overstate risks and prevent most or all mixed wastes generators from realizing the benefits of disposal under the new regulation even if such disposal were truly of little concern; using less conservative assumptions, however, might allow disposal of some wastes under conditions that do not provide sufficient protection. The criteria are intended to prevent any person from receiving an unacceptable radiation dose during any year following emplacement. The highest estimated annual dose after emplacement, or "peak dose," is therefore the limiting variable.

2.2 Charge to the SAB

Given the issues noted above, the ORIA requested that the Science Advisory Board's (SAB) Radiation Advisory Committee (RAC) provide advice on its modeling efforts by responding to the following three Charge questions:

Question a) Having relied on extensive site characterization data from existing and potential low-level radioactive waste disposal facilities, does the EPA dose assessment reasonably cover the range of hydrogeologic and climatic settings that might be used for disposal of low-activity mixed waste?

Question b) What modeling time frame does the Committee recommend be used to project potential doses from disposal of low-activity mixed waste? Does a 1000-year time frame provide an adequate technical basis for setting regulatory limits?

Question c) Given the modeling approach described [in the Agency's presentation], and the available knowledge regarding concrete durability and modes of degradation, is it reasonable to assign a "high" release rate for the duration of the simulation? Does the SAB advise an alternative approach, such as assuming a lower release at the start and increasing it incrementally over the modeling period, thereby mimicking the gradual deterioration of the concrete?

3. DETAILED FINDINGS AND RECOMMENDATIONS

In general, the Agency has provided a modeling approach that is consistent with its previous analyses of radioactive waste issues and that may be reasonable for establishing acceptance criteria for the disposal of mixed wastes in RCRA-C disposal cells. The proposal is, for the most part, clearly described in the materials presented to the Committee, which struck a good compromise between being comprehensive and being brief (See U.S. EPA/ORIA 1998a through 1998m). The Committee provides below some suggestions that may help improve the modeling effort for the task of managing LAMW.

The Committee is supportive of the Agency's intent to find a partial solution to the vexing problem of disposing of wastes that contain both RCRA-regulated hazardous constituents and AEA-regulated radioactive constituents. It is entirely reasonable that some level of radionuclide concentrations should be acceptable for disposal in RCRA-C waste management units. The challenge is to define criteria that provide sufficient protection from long-term risks yet qualify a substantial portion of mixed wastes for disposal under less onerous requirements than currently used for low-level radioactive waste (LLRW) disposal.

The Committee's responses to the three Charge questions appear below. However, the Committee believes that those responses are to some extent conditioned on choices about broader--and probably more important--issues in the modeling and regulation of LAMW disposal. Therefore, we offer in Section 3.4 comments beyond the Charge. We also provide, in Appendix A, some detailed comments designed to improve any Technical Support Document that is eventually issued in conjunction with a proposed regulation.

3.1 Extent of the EPA Dose Assessment (Question a)

Charge question (a) asked for comment on EPA's proposed dose assessment, focusing on its adequacy across the wide range of climatic and hydrogeological settings which might be encountered in disposing of low-level wastes.

The site characterization does not entirely cover the range of settings for disposal sites. The Committee believes that some existing RCRA-C sites and possible future RCRA-C sites in the states of Alaska and Hawaii, as well as the territories of Puerto Rico, Guam, and trusteeships are not adequately bounded by ORIA's use of three existing DOE sites to cover the range of hydrogeologic and climatic settings. In order to use the ten selected DOE sites as a point of departure, EPA must demonstrate that they are similar to the 22 currently operating RCRA-C disposal facilities, as well as possible future facilities outside the conterminous USA. The similarity must not only include hydrogeologic and climatic characteristics, but other siting and design issues such as

a) Are any of the existing and potential future RCRA-C sites in the 100-year or 500-year flood plain? How should ORIA deal with potential future changes in the flood plain area due to upstream development, etc.?

b) Do the sites have similar depths below the waste to the groundwater table? What is the thickness, nature, and extent of infiltration in the unsaturated zone?

c) Are the sites similar with respect to the hydraulic conductivity of their unsaturated zones? Are other geochemical processes important to the movement of radioactive materials?

d) Are the sites similar with respect to fracturing of the underlying strata?

e) Are seismic characteristics that might influence the stability of containment similar between the RCRA-C and DOE sites?

f) Are the ecological systems of the two sets of sites similar? These systems can influence the probability of cap degradation.

g) Are the containment designs of the RCRA-C facilities similar to the DOE facilities?

h) Do the DOE sites experience similar freeze-thaw and snow pack buildup, as the RCRA-C facilities?

i) Are dry sites with shallow ground water depth represented by the DOE sites? If ORIA believes that such sites are not relevant, it should explain why not.

j) Conditions in, and properties of, the waste and surrounding geological materials control the rate of release and transport of chemical and radioactive contaminants from the waste to the accessible environment. Important site considerations are the compositions, proportions and distribution of radioactive and hazardous wastes at a site, waste and soil redox and pH conditions, the presence of reactive materials (i.e., highly sorptive), and biological activity. Do the ten DOE sites take into account the expected variability of these wastes, site conditions and properties?

Without this information, ORIA cannot assume that its "bounding analyses" truly bounds the RCRA-C sites. However, the Committee is not recommending inclusion of site characteristics that would clearly be found unacceptable for future RCRA-C facilities.

Furthermore, Question (a) (See Section 2.2) as framed by ORIA seems overly narrow. While it is desirable to select sites to bound important potential site conditions and characteristics, the ultimate goal should be to bound probable site *performance*. ORIA should consider enhancing its approach to include additional site characteristics (See discussion of the Total

Systems Performance Analysis approach in Appendix B). Model predictions of the long-term performance of potential LAMW sites should be validated as much as possible against the actual performance of existing waste sites. In some cases, there are sufficient historic data to validate 30-year predictions of hazardous waste site performance, and a few decades of performance data for several radioactive waste sites are available. However, ORIA is proposing to make predictions of radionuclide releases for 1,000 yrs or more. Should it be using *performance* data for existing waste sites as a basis for modeling predictions for proposed LAMW sites?

In the overview document (U.S. EPA/ORIA 1998a, 1998b), the EPA presents model calculations to predict the concentrations of different radionuclides assumed to be mobile or immobile in the typical site. All waste sites are apparently considered oxidizing, based on the radionuclides that ORIA classifies as mobile (e.g., U, Np, Se, Tc). This assumption will probably be true in cold and/or dry settings. However, in wet (high rainfall), warm climates in the presence of reactive organic wastes or organic-rich soils, (near-field) subsurface conditions are more likely to be reducing, which could make these radionuclides immobile. For other radionuclides, reducing conditions might enhance mobility.

In the generic characterization document (U.S. EPA/ORIA, 1998f), it appears that ORIA has considered an extensive list of site-specific physical and hydroponic parameters in the PRESTO modeling calculations to predict performance of the ten DOE sites in the screening step. It has assumed single values for all parameters in the calculations, whereas a probability distribution of values using a Monte Carlo approach, for example, would give more realistic results and provide an estimate of the uncertainty.

Apparently the only geochemical inputs to predictive modeling are the radionuclide-specific distribution coefficients (K_d) (U.S. EPA,/ORIA, 1998i, p. 2), which the document states will vary with soil type. Values of K_d for individual actinide elements in particular can vary by up to five orders of magnitude depending not only on soil type (i.e., soil mineralogy and particle size), but also on soil and waste pH,[5] redox conditions, the presence of reactive organic matter, and biological activity (Langmuir, 1997). The chemical and biological reactivity of the mixed waste (of its organic, inorganic and radioactive substances) and its interaction with surrounding soils will control the release rate of the radionuclides. The climatic and general hydrogeologic conditions at two sites could be identical. However, differences in the composition, reactivity and relative amounts of chemical and radioactive materials in different wastes, and differences in the behavior of reactive minerals present in the soil and underlying groundwater systems, could result in vast differences among sites in the timing and amounts of specific radionuclides that arrive at adjacent wells.

As or more important than depth to bedrock and thickness of the unsaturated zone (UZ), is the nature and extent of infiltration through the UZ, which will reflect the structure and stratigraphy of 'soils' in the UZ. For example, does flow at and under the waste site occur in

[5] Cementitious materials in the waste, if fresh, will buffer the (near-field) pH near 10.

coarse-grained materials (permeable sands and gravels, for example), or in less permeable silts and clays? At sites with poorly developed or thin soils as on hill slopes or in mountainous areas, waste sites may be emplaced in partially weathered bedrock, in which case infiltration of leachates carrying radionuclides may move easily down fractures in the bedrock to groundwater. A dual permeability modeling approach is needed in sites with fractures; an "equivalent continuum" model is not reliable for travel-time calculations.

The only geochemical process mentioned is the ion exchange behavior of soils, which is only one of the geochemical processes or conditions of importance to radionuclide releases. Other processes include specific adsorption by solids in the waste or soil (for trace radionuclides, generally more important than ion exchange), precipitation or co-precipitation of radionuclides with solids, waste and soil redox conditions, the presence of substances that can form strong complexes with radionuclides, increasing their mobilities, among others. Important soil and waste characteristics that control radionuclide mobilities include: (1) reactive organic matter content[6] and its amount relative to that of the radionuclides (as noted above); (2) temperature[7]; (3) oxygen flux rate; (4) moisture content and infiltration rate, and (5) the presence of solids in the soil that are sorptive for actinides (e.g., Fe and Mn oxides, phosphates). All of these characteristics can change along the flow path from source to well.

Although the Committee recognizes that ORIA is attempting a generic analysis that cannot take into account all the site-specific characteristics of real sites or the properties of real combinations of wastes, we recommend that ORIA take a broader look at the range of radionuclide leaching and transport behaviors that might occur at real RCRA-C sites. Discussions with modelers in the RCRA or Superfund programs could be helpful in this regard, as would a perusal of the EPA Environmental Sciences Division's web page on databases and software.[8] This source contains several modeling structures that might help in exploring this issue. At a minimum, ORIA should discuss what steps it has taken to determine the effect of the variables mentioned above on model results and why it believes that using a short list of DOE site characteristics in the PRESTO model will be sufficient.

3.2 Suitability of the 1000-year Time Frame (Question b)

The Committee concluded that a sensitivity analysis of the modeling time frame could provide potentially useful information on the variation of peak dose with time horizon, especially for less mobile radionuclides with long half-lives. The Committee did not reach consensus, however, on how ORIA should weigh projections for the longer periods against the more reliable projections for shorter periods. The factors that contributed to the Committee's lack of consensus centered on the consideration of four issues – scientific, future land use, public

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[6] The decay of cellulosic materials to form ligands that can complex the actinides, for example.

[7] Temperature accelerates biological activity and waste material breakdown.

[8] see http://www.epa.gov/crdlvweb /databases/datahome.htm

acceptance, and economic viability. The comments below reflect considerations that should influence ORIA's ultimate choices about time frame. Because these comments represent the different perspectives of individual Committee Members, they do not signify a Committee consensus.

3.2.1 Scientific Issues

The Committee addressed seven major scientific issues, outlined below

a) **Capturing the time of peak dose:** Clearly, some radionuclides with long half-lives and low mobility will not attain maximum concentrations in groundwater within 1,000 years, especially for the "dry" scenario with a very thick unsaturated zone . The New York State Department of Environmental Conservation performance assessment modeling in support of a LLRW disposal facility used a 10,000-year time frame. The results of this modeling showed the peak off-site dose to the public occurred 1,200-2,000 years after closure for most near surface disposal scenarios modeled. Whether or not a failure to capture the time of peak dose will be significant from a scientific standpoint depends on the scenario and policy assumptions that accompany the model (See land use and concrete containment discussions). If the model time frame were extended to 10,000 years, it would capture the peak dose for most if not all radionuclides, and it should also account for the peak dose from in-growth of decay products.

b) **Limited life of controls:** On the basis of design conservatism of facilities and the stress system in the near-surface environment in which they are operated, the controls that may be exerted on radionuclide doses by RCRA-C facilities layers can be assumed to be zero after a few hundred years. Maintenance activities under a "perpetual care" commitment by the facility managers and natural hazards can influence the specific time range. By the time the service life is attained, the fatigue-type stresses that are common in the near-surface environment (freeze-thaw, dry-wet cycles, expansion-contraction, weathering, burrowing by animals, possible physical erosion of covering soils, etc.) would have created and/or extended flaws in the system to change the fluid entry and release mode from permeation to pipe-flow. If the analysis is extended to 1,000 years or more, the influence of containment would then be entirely ignored in the analysis of releases after 300-400 years.

c) **Definitions of failure:** One of the most difficult questions to answer on containment system performance is, "What is failure?" The failure of a component (cover or liner) may not necessarily mean the failure of the system that contains many components. Are the components connected structurally or functionally in parallel or in series? Structural failure may not always mean functional failure. For the purposes of this project, ORIA should focus on a definition of system functional failure that considers failure as the release of radionuclides sufficient to cause a dose above the dose criterion in a person residing at a specified location adjacent to the site.

d) **Variable time frame as a function of LAMW composition:** The range of the possible radiological compositions of candidate wastes is not well defined. It appears that there is greater uncertainty about which of the long-lived radionuclides may be present in commercial mixed waste than about the short-lived radionuclides. If there were no long-lived radionuclides, there would be no need for modeling beyond 500 years. However, if long-lived radionuclides are present, and the modeling out to 10,000 years demonstrates that the dose standard would be exceeded at the time of the peak dose, the radionuclide con Therefore, one way for ORIA to limit the modeling time frame is to verify that certain long-lived radionuclides would not be present in commercial mixed waste, or alternatively specify that they must not be present in wastes destined for RCRA-C disposal. Which radionuclides may be subject to such consideration could be identified by conducting runs at several time scales (e.g., 100, 300, 1,000, 3,000, and 10,000 years) and comparing peak doses for the various runs.

e) **Conservatism of modeling assumptions:** Modeling beyond 1,000 years may be unrealistically conservative and unrealistically uncertain. Among the conservative assumptions are a) that all waste sites are always oxidizing, which ensures that certain radionuclides are always modeled as mobile regardless of the waste form or waste composition, and b) that no reactions or processes within the waste, in the unsaturated zone, or in the groundwater system other than radioactive decay and simple adsorption by soil will prevent the release of radionuclides to the environment. In the presence of concrete, many of the so-called “mobile” radionuclides in the waste would become less mobile, at least for short times.

f) **Effect of climate on long-term predictions:** A more comprehensive performance assessment analysis might show that for some sites, radionuclide releases can be predicted to be low and not an issue for times up to 1,000 years. Such sites are likely to be in arid climates with thick, well drained unsaturated zones. It might be necessary to limit LAMW disposal to such sites. In wet, humid climates, the performance of sites for near-surface disposal of LAMW cannot be predicted reliably for time spans beyond a few hundred years. Thus, radionuclides with longer half lives, such as Np, would still be a problem.

g) **Consistency with other waste regulations:** The Agency should also consider what time frame it would use if it regulated hazardous waste disposal with risk-based rather than technology-based rules. An illustrative example would be lead, which has an infinite half-life, physical-chemical properties similar to many of the naturally occurring radionuclides, and a dose-response relationship without an established threshold. Certain carcinogenic heavy metals also could be considered. While NRC regulations require site characteristics be considered for a minimum of 500 years, most performance assessments for LLRW sites are run to 10,000 years. Should hazardous waste environmental fate analyses be modeled to 10,000 years?

3.2.2 Future Health Risk and Land Ownership Considerations

The Committee discussed two primary issues:

a) **Long-term societal changes:** One thousand years may be unrealistically long given the likelihood of substantial changes in public health and social conditions. Currently, cancer is the endpoint for health risk from radionuclides. It is certainly possible that within a 1,000-year time frame, cancer will become a disease of less concern because of advances in prevention or treatment; cancer as an endpoint could become largely irrelevant. Likewise, society may view radiation risk in a much different way. By suggesting modeling out to 10,000 years, we may not even comprehend what forces will dominate the pathways for exposure. It is when we consider future societal decision-making that the 10,000-year modeling scenario appears speculative indeed.

b) **Land ownership issues:** Part 61 licensed LLRW sites must be owned by Federal or State government following closure and a post-closure observation period. All DOE facilities are on Federal government owned sites. It is very important to consider site ownership by the Federal and State government when discussing modeling time frames. While no government has lasted 10,000 years and government agencies do not always meet their obligations as environmental stewards, government ownership of a site is a clear commitment by a civilization to maintaining the integrity of a LLRW disposal site over time.

RCRA-C facilities have no such requirement. Profit-making corporations own RCRA-C facilities. They have different responsibilities to their shareholders, and any post-closure land use scenario is possible, constrained only by local planning and zoning boards' interpretation of RCRA guidance.

3.2.3 Public Acceptance

Although the Charge to the SAB is specific to providing an adequate technical basis for setting regulatory limits, the Committee members have enough experience with public acceptance of LLRW disposal facilities to comment on this aspect of deciding on appropriate modeling time frames. It appears that modeling can be a useful tool for describing the behavior of radionuclides at an RCRA-C site. Particularly important is the fact that the site is already in operation accepting hazardous waste, and was not sited using Part 61 characteristics. Therefore it must be made crystal clear to the public that the site will operate within radiation standards. If the site cannot be shown to be “safe” at the time of the peak dose, it is likely not to win public acceptance. So if the site is modeled to 1,000 years, the public may not be convinced that it should approve the disposal of radioactive material there. However, if conservative assumptions show that, at the time of peak dose, the site will still be adequate to protect public health, public acceptance is more likely. If the RCRA-C sites that are permitted to accept LAMW commit to “perpetual care,” acceptance would be further enhanced.

Table 2 on pages 6 through 8 of the Modeling Time Frame document (U.S. EPA/ORIA, 1998g) has 30 of 48 radionuclides peaking at 1,000 years in the 1,000-year modeling period, demonstrating that the peak dose was not captured during the 1,000-year time frame. Attachment 3 on page 3.1 of the same document has ^{129}I and ^{99}Tc peaks that are much higher at 10,000 years than at 1,000 years. The public will surely notice that modeling to 1,000 years does not show peak dose for all radionuclides. Therefore, modeling to 10,000 years would be useful.

On the other hand, the public may be accepting of model predictions of fate and transport for a time frame of 100 years. The use of 10,000 years could raise serious questions concerning the degree of uncertainty and possibly the credibility of the entire approach for estimating future health risks.

3.2.4 Economic Considerations

The entire premise of the EPA’s proposed LAMW disposal rule is to provide a lower cost option for RCRA-C facilities to apply for Part 61 licenses so that they could also accept mixed waste. This proposed rule will assist some research facilities, medical facilities, and utilities by providing additional disposal options for mixed wastes. These facilities currently store this waste and are waiting for a place to dispose of it in a cost-effective manner.

If the modeling to 10,000 years puts such constraints on the radionuclide concentrations that no RCRA-C facility applies for the Part 61 license, the purpose for the proposed rule is lost. RCRA-C facilities have to be able to make a profit on the waste or they will not accept it.

However, if modeling to 1,000 years does not convince the public to accept radioactive wastes into RCRA-C facilities, the rulemaking will also be in vain. Currently, the most expensive item in siting a new disposal facility is winning public acceptance.

3.3 Modeling Release Rates (Question c)

The last Charge question asked the RAC to comment on EPA's approach to modeling release rates over time, taking into consideration the available knowledge regarding concrete durability and modes of degradation.

The Committee concluded that the key issue in this third question was the impact of the deterioration assumption on the calculation of the peak annual dose.

3.3.1 Technical Issues

In order to determine the limits for radionuclides in mixed waste to be disposed in RCRA-C facilities, doses were calculated for unit concentrations of specific nuclides in the wastes. Doses were modeled assuming that the waste was solidified in concrete, using an inexpensive, normal Portland cement. This assumption could be conservative as long as this type of treatment is the minimum RCRA requirement. Use of special types of cement/concrete mixtures that would minimize the potential for degradation, i.e., sulfate resistant cement (U.S. EPA/ORIA, 1998l, citing SMI, 1998) or specific construction and reinforcement as described in the New York State Final Generic Environmental Impact Statement for Low-Level Waste Landfills (NY,1993) could be addressed in site-specific radioactive materials license conditions.

The release rates from concrete used in developing the dose estimates are based on the assumption that the concrete degrades over time, releasing all radionuclides at a constant (relative) rate. This rate was assumed to be 0.001 per year, based on the diffusion coefficient for tritium in concrete. The release rate assumes a first-order reaction; that is, the rate of release is proportional to the inventory remaining in the waste form. Values of 0.0005 per year and 0.005 per year for the relative release rate were also used in the dose calculations. The initial concentrations in groundwater were determined using radionuclide-specific distribution coefficients (K_d) for the concrete/water partitioning, and were derived from the literature. The retardation factor in the concrete was applied in the calculation in the same manner as it is in the calculation of retardation in soils.

The rate of release has a significant effect on the calculation of a peak dose via the groundwater pathway. For ^{3}H, the fractional increase in dose is approximately equal to the fractional increase in release rate for tritium. For ^{129}I, however, the dose increased by a factor less than 2 when the release rate was increased by a factor of 5, indicating a non-linear response for this radionuclide. ORIA states, however, that changing the release rate does not affect the year in which the peak dose occurs for this radionuclide.

ORIA also states that the constant release rate assumption results in peak doses not significantly different from the doses that would be calculated using a variable release rate, i.e., a slow initial rate increasing over time as the concrete degrades. While degradation rates for concrete could not be quantitatively determined from the available literature, progressive degradation is a more reasonable scenario (U.S. EPA/ORIA, citing SMI, 1998). The Committee recommends that a simulation be performed to verify, at least qualitatively, that the constant loss rate assumption is reasonably--but not excessively--conservative, for all radionuclides.

For example, an exponential deterioration model can be used to scale its structural properties with respect to time (e.g., porosity).. Then for each time segment within the modeling time frame, the relevant magnitude of the structural parameters can be fed into the selected leaching model to estimate release rates. Monolith leaching models such as those that relate to the American Nuclear Society's American National Standards Institute (ANSI) 6.1 test can be adapted for use.

The concrete deterioration model also interacts with the containment failure models. There is no scientific basis for ORIA's assumption that at the time the liner fails completely (100% failure), the cover would have failed only by 10%. Actually, one could argue that the cover is likely to fail before the liner because it is subject to extremes and reversals in temperature and moisture conditions and access by burrowing animals and plant roots. A deterioration pattern could be analyzed based on the transport-related characteristics of the containment system. Then, depending on the time frame of concern, the relevant magnitude of the parameter could be fed into the model instead of specifying an arbitrary failure rate or ratio (See Figure 1).

Although RCRA-C facilities incorporate polymeric membranes in both the cover (cap) and lining systems, ORIA's analysis focuses only on soil layers. Significant decreases in radionuclide release rates would be obtained if engineering barriers were included in the analysis. Essentially, the barrier system is the second line of defense for the radionuclides, after the concrete encapsulation itself. Error in the release rates would propagate throughout the entire analysis, including the calculation of dose rates.

For radionuclides with short half-lives, the doses could be significantly overestimated by assuming a high constant loss rate. In the initial phases, when the concrete remains intact and the loss rate is, in fact, very low, the short-lived radionuclides would decay before release, thus producing very little, if any, dose. On the other hand, for longer-lived radionuclides that decay to progeny with higher bioaccumulation potential and dose coefficients (e.g., ^{230}Th to ^{226}Ra), the assumption that the loss rate is constant may not be conservative, depending on the effect of retardation (K_d) as the radionuclides move through the concrete and soil matrices.

The emphasis on concrete degradation assumes that the treatment option for all of the mixed waste potential candidates for disposal at RCRA sites would be solidification in concrete. For some wastes, such as contaminated soils, lead bricks or lab trash, solidification may not be the optimal treatment. Under the Land Disposal Restrictions (LDR), moreover, some hazardous wastes require treatments other than solidification in concrete. The Agency should either exclude such wastes from the rulemaking on LAMW or assure the required LDR treatment is more restrictive than solidification in concrete. For example, is the requirement for amalgamation of mercury more restrictive over 1,000 or 10,000 years than solidification in concrete? The concrete waste form may not be the most conservative assumption. Even for concrete, the possible influence of the hazardous waste constituents on concrete stability should be considered.

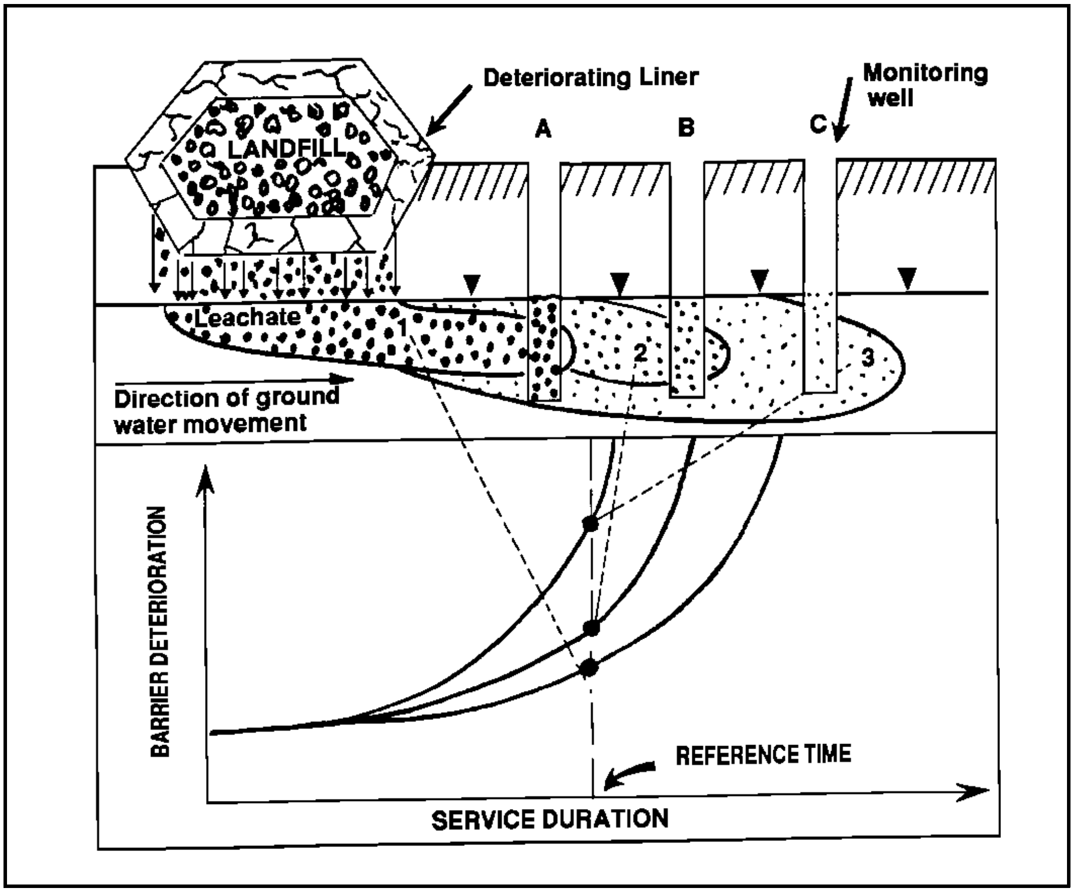

Figure 1 Barrier Performance Assessment through Mathematical Modeling and Monitoring (Provided courtesy of Dr. Hillary Inyang, Chair, SAB/EEC).

3.3.2 Science Policy Issues

The question of whether the most conservative assumptions for the disposal options are the most effective in reducing overall risk should be addressed in the background considerations for the RCRA mixed waste standards. Unduly restrictive limits for disposal at RCRA-C facilities may significantly reduce the effectiveness of this option. Wastes that currently cannot or should not be disposed at licensed LLW sites or conventional mixed waste facilities are generally stored at or near the site of generation. Although such wastes are subject to inspections and other requirements designed to ensure their safety during storage, indefinite accumulation and storage of mixed waste at the site of generation clearly runs counter to current waste management philosophy. Waste stored at the generator site is usually closer to workers and the public than would be the situation with disposed waste. This proximity increases the probability of human contact with the waste as a consequence of normal handling, accidents and natural disasters and thus may increase the health risks over what they would be if the wastes were disposed of at RCRA-C facilities. The goal of this effort should be to reduce overall risk. Therefore, unnecessary conservatism in setting disposal limits may be counter-productive.

The Committee recommends that ORIA investigate the types of waste that might fall under the provisions of the proposed rule and the conditions under which they are currently stored and, to the extent possible, characterize the health risks of plausible failure scenarios. The risk assessment principles should be similar to those used in the present modeling exercise, in the sense of using similar degrees of conservatism. Ideally, both analyses would have elements of a quantitative uncertainty analysis. Then, the probability of improving the overall risk balance for different sets of waste acceptance criteria could be studied. (Note: this comment applies to any assumption posited on the grounds of conservatism.)

3.4 Additional Issues

3.4.1 Modeling Structure

ORIA has selected the PRESTO model to conduct the acceptance criteria modeling. Although the Committee understands that PRESTO has a long history of use in the Agency and that ORIA has considerable confidence in the applicability of its results for the intended purpose, we advise that ORIA be prepared to justify its use in the Technical Support Document that will eventually be produced to support any rulemaking. Such justification might include answers to the following questions:

a) Has it been benchmarked (e.g., through BIOMASS or another effort for cross-comparison of models)?

b) Can it adequately simulate the role of geochemical processes in enhancing or retarding radionuclide transport (not just K_d and radioactive decay)?

c) Can it consider the effects of variations in the composition and form of mixed waste as emplaced on radionuclide releases?

d) Does it account for the ingrowth of decay products after disposal of the parent radionuclide for which the criteria are calculated? (Decay products are not included in dose tabulations in some EPA publications.)

e) Is it particularly suited for the spatial scale of the analysis (e.g., a potable water well 50 m from the edge of the RCRA cell)?

f) Has it been updated and enhanced to be consistent with the current state-of-the-art of multimedia health risk models? With RCRA modeling assumptions?

Any other assurances of its applicability and reliability would also be welcome. For example, ORIA might consider using a second relevant model as a check on the doses predicted for unit concentration of each radionuclide. Reasonable agreement would support the choice of

PRESTO. Disagreement, however, would require ORIA to investigate the causes of the disagreement and make informed choices about any needed adjustments to its modeling.

ORIA stated that it would use the "unity rule" for judging the acceptability of LAMW containing more than one relevant radionuclide. Under the unity rule, the concentration of each radionuclide in a candidate waste would be divided by the corresponding criterion concentration and these fractions would be summed over all radionuclides. If the sum of fractions is less than 1.0, the waste would be found acceptable for disposal. This rule may be unnecessarily restrictive for certain combinations of radionuclides. For example, if a waste contained both ^{3}H and ^{14}C at their respective concentration limits based on the reference dose, application of the unity rule would prohibit its disposal at a wet RCRA-C facility (e.g., one with characteristics similar to Fernald). However, the peak dose for ^{3}H is reached in about 100 years but the peak dose for ^{14}C is not reached until 1,000 years or more after the liner is breached. Therefore, the dose to an exposed individual could not exceed the reference dose in any year. To overcome this unintended consequence, radionuclides could be classified according to similar peak dose time frames and the unity rule applied only within those time classes. The Committee recognizes that such a procedure would increase the complexity of the contemplated rule and might appear to be in conflict with similar NRC procedures.

Presumably, the eventual Technical Support Document will describe more clearly the process of determining acceptance criteria in concentration units starting with a policy choice about the acceptable reference dose. If the Committee understands ORIA's intent correctly, concentration would be the principal if not the only determining criterion for waste acceptance. However, it seems likely that the potential peak dose for a given concentration in waste would also depend on the total quantity of wastes of that concentration deposited in the modeled site. ORIA appears to be currently assuming that only a small fraction of the total waste in the RCRA-C cell would be LAMW at the criterion concentration. But there appears to be no restriction against a larger fraction nor any credit given for a smaller fraction. ORIA might consider additional limitations on the total quantity of any one long-lived Radionuclide allowable at a RCRA-C facility of given capacity. If it does so, it should also consider the implications of such a limitation on the unity rule.

Some pathways of exposure seem to have been excluded from the modeling. For example, it is not clear that evolution of radon or other volatiles from potable water use in the home has been treated, and it is clear that soil ingestion and dermal contact with soil have not been included, even though the on-site residential ("immobile") scenario postulates excavation of soil from the disposal cell during construction. While dermal absorption of inorganic hazardous chemicals is usually unimportant, the same is not always true for soil ingestion, which is frequently more important than soil re-suspension, a modeled pathway

Many of the existing RCRA-C disposal facilities have SWMUs that contain non-stabilized hazardous wastes. EPA should consider whether or not these wastes could enhance the degradation of LAMW containment or the mobility of radionuclides after release. Even for the licensing of new facilities with stabilized wastes, the potential for enhanced mobility from the co-disposal of hazardous and radioactive wastes should be considered.

For the mobile (groundwater) scenario, there are different results for the assumption of segregated vs. random emplacement. However for the immobile (intruder) scenario, separate calculations are not made for assumptions of segregated vs. random emplacement. Because the immobile scenario postulates an intruder, exposure would seem to be strongly dependent upon whether the waste was segregated or placed randomly, suggesting that separate calculations are appropriate. The detailed assumptions for the segregated vs. random emplacement should be better described.

On p.2 of the Overview (U.S. EPA/ORIA, 1998b), EPA apparently is using a 1990 NRC survey published in 1992 as NUREG/CR-5938 (U.S. NRC, 1992) to estimate the volume of commercial mixed waste generated in the U.S.. Pollution prevention and waste minimization efforts have significantly reduced annual mixed waste volumes since then. On the other hand, the decontamination and decommissioning of nuclear power plants and naval reactors in the next ten years may result in a significant increase in commercial mixed waste volumes.

On p.11 of the Overview (U.S. EPA/ORIA, 1998b), ^{3}H and ^{14}C in waste gases are assumed to be negligible due to prior treatment by incineration. Based on the large volumes of wastes containing these radionuclides being generated at commercial sites, this assumption needs to be justified. Also, EPA should consider modeling root uptake of these radionuclides in cover vegetation.

On p.13 of the Overview (U.S. EPA/ORIA, 1998b), it is stated that a subset of radionuclides from Table 4 were included in the mobile modeling scenario. ^{90}Sr was not included in the list of the mobile radionuclides, and was listed in Table 7 as a Radionuclide that resulted in no doses from mobile or immobile scenarios. EPA should reexamine the scenarios in view of ^{90}Sr's historic problems at LLRW sites.

3.4.2 Science Policy Issues

Given the large range in the results for the different environments modeled, one has to question the utility of a single set of Radionuclide concentration limits, which would, of necessity, have to apply to the worst possible environment. The large differences for the “dry” and “wet” sites suggest an approach of developing at least two sets of concentration limits. For example, Type 1 sites could include sites in arid climates with deep, well drained unsaturated zones and sites in semi-arid climates in groundwater recharge zones with deep, well drained soils if the latter were capped with compacted clay, contoured to export runoff, and vegetated to minimize infiltration. It would be easier to predict the long-term performance of such sites than sites in wetter settings. Type 1 sites could perhaps accept long-lived radionuclides. Type 2 sites would be those in wetter settings with a shallower groundwater table. Because of the difficulty of defensibly predicting their performance for long times, and the greater risk of radionuclide releases, Type 2 sites might be limited to the disposal of LAMW containing only short-lived radionuclides. In addition, it should be made possible for an applicant to demonstrate, through site-specific modeling, that the dose limit could be met with alternative concentrations. Again, the Committee recognizes the additional complexity of such a procedure and that it might appear to be in conflict with similar NRC procedures.

In its eventual technical product, ORIA should attempt to tie together the modeling assumptions and health risk criteria between the hazardous chemical constituents and the radioactive constituents of the mixed waste. The proposal must be seen to be consistent with the objectives of the current RCRA protection system even if not with its specific requirements. The Technical Support Document should provide background on the similarities and differences between chemical and radiation risk management and how the modeling dealt with them.

As described to the Committee, the LAMW proposal would apply to a rather limited range of wastes generated by “commercial” activities and classified as both RCRA hazardous waste and AEA Class A LLRW, and the only new disposal alternative would be in a RCRA-C facility. However, the modeling effort has many additional potential uses, including decisions about:

a) disposal of wastes containing RCRA hazardous and TENORM, which are not regulated under the AEA,

b) disposal of wastes containing Toxic Substances Control Act (TSCA) substances and either AEA or TENORM radioactive constituents,

c) disposal of qualifying Class A radioactive wastes that do not contain RCRA hazardous components at RCRA-C facilities, and

d) defining “de-minimis” concentrations for radionuclides that would enable non-hazardous very low level radioactive wastes to be disposed in RCRA-D (sanitary) landfills.

The Committee recommends that these potential uses be kept in mind when making modeling choices for the current proposal. ORIA should also examine the forthcoming NCRP report on waste classification for other possible uses. Having a wider range of modeling uses will better justify the time and effort spent, which may otherwise seem excessive for the limited quantities of waste currently thought to fall under the proposed rule. In making this suggestion, the Committee is well aware that there may be legal, economic, or political reasons for EPA to disallow disposal of some of these wastes in RCRA facilities even if they meet the dose criterion.

The Committee recommends that the eventual Technical Support Document discuss how the Agency has responded not only to these comments but also to the RAC’s 1985 recommendations (SAB, 1985).

3.4.3 Other Policy Issues

The EPA overview document notes that "reference doses" -- presumably the doses that will limit the allowable concentrations of radionuclides in the qualifying waste--are still to be determined. The Committee notes that the goal of risk harmonization would be furthered if such doses corresponded to risk levels consistent with those that would be used as guidelines for the regulation of hazardous chemical waste (SAB, 1992).

A waste that contains radioactive materials AND hazardous constituents is clearly more hazardous than a waste that contains the same levels of only the radioactive or only the hazardous components. On purely scientific grounds, it is not logical to allow a mixed waste to be deposited in a RCRA-C facility when a purely radioactive waste of identical radionuclide content would not be permitted. The Committee recognizes that EPA may wish to discourage disposal of purely radioactive waste that would otherwise meet the acceptance criteria for LAMW because it might disturb established low-level radioactive waste policies or Compact relationships. Such a policy, however, might encourage waste generators to manage wastes so that they could be disposed of as LAMW instead of LLRW.

The cost of disposal of LLRW at a Part 61 licensed site is much higher than that for hazardous wastes at RCRA-C facilities. In addition, access to the nation's LLRW disposal sites for many states is very tenuous. Thus, LLRW generators may find disposal of LLRW as LAMW in a RCRA-C facility is cheaper and possibly their only disposal option. Avoiding this perverse incentive may prove difficult under the LAMW rule as currently contemplated.

It is not clear to the Committee that EPA has considered whether the LAMW rule would cover mixed radioactive and TSCA wastes (PCBs, asbestos) or mixed wastes containing uranium mill tailings.

The Agency should consider whether accepting radioactive wastes at a RCRA-C facility changes the liability between radioactive waste generators and disposal facility operators. The issue of "taking possession of the radioactive materials" in the LAMW needs to be resolved.

Since RCRA-C facilities currently accept foreign hazardous wastes, will mixed wastes from other nations be allowed to be disposed of under the LAMW rule? In particular, can LAMW from Canada and Mexico be excluded under NAFTA? How does this affect EPA's estimate of the quantity of waste that might fall under the proposed rule?

Part 61.56(a)(7) allows gaseous LLRW disposal under 1.5 atmospheres at 20 degrees Celsius. Will the LAMW rule allow for the disposal of mixed gaseous wastes?

APPENDIX A - DETAILED COMMENTS

a) In any final documentation of the modeling, SI units should be used with the traditional units in parentheses.

b) In the final work product, the Agency should be sure that undue certainty is not implied by the use of too many significant figures.

c) Clarify what is meant by dose. Several different wordings appeared in the Committee's briefing materials, most of which appeared to be synonymous. If differences are intended, the nomenclature should be clearly defined. If not, uniformity is desirable.

d) The meaning of commercial is not obvious. It seems to be used in one sense to qualify the facility and in another to qualify the waste. The use of this term should be defined.

e) If the principal focus remains on wastes that are regulated under the AEA, consider eliminating from the lists radionuclides such as ^{40}K that probably are never considered germane to AEA control.

f) Only cancer is considered a relevant endpoint for risk assessment. ORIA should be careful to justify why it believes that other potential effects of radiation, such as birth defects, are not relevant at the dose criterion eventually selected.

g) Some of the data in Attachment 1 for the Idaho National Engineering Environmental Laboratory (INEEL) appear to be in error, unless a great deal of conservatism is intended. The thickness of the vadose zone at INEEL is much greater that 41 m, unless perched water bodies are meant, or basalt is excluded. At the current radioactive facility at INEEL, the depth to the aquifer is nearly 200 meters. The thickness of the aquifer is much greater than 12 m, and in fact is so thick that its thickness is unknown. The depth of the aquifer is much greater than 12 m, in fact it is so deep that it is unknown. Is 12 m an artificial thickness? Although the INEEL was not chosen as one of the three sites used to bound the various scenarios, these possible discrepancies suggest that the data used for the model parameters at the other sites should be examined critically, or at least explained. Similarly, the climatic description for Rocky Flats appears questionable. Note also inconsistencies between Attachment 1 and Table 2 of the Overview regarding depth of vadose zone (U.S. EPA/ORIA, 1998b).

h) In Table 2 on page 9 of the overview, the meaning of 31/300 for "end of events" is unclear (U.S. EPA/ORIA, 1998b).

i) In Table 2 on page 5 of the generic characterization document, the qualitative descriptions should be accompanied by numeric ranges to avoid confusion (U.S. EPA/ORIA, 1998f).

APPENDIX B - TOTAL SYSTEM PERFORMANCE ASSESSMENT APPROACH

The proposed high level waste repository for commercial spent fuel at Yucca Mountain would be emplaced hundreds of meters below the land surface above the water table in a relatively dry and geologically stable setting. Even so, predicting the fate of radionuclides to be buried in the repository for times of 1,000 yrs or longer has been highly contentious. After many years of being criticized because their predictive approach did not properly consider and weigh the relative importance of all important site variables and processes, the DOE adapted a comprehensive Total System Performance Assessment (TSPA) modeling approach. This approach has led to predictions of site performance including radionuclide release rates in terms of their probability.

ORIA might consider using a similar approach, being careful to select the important variables that will influence future radionuclide release rates from mixed waste sites. The importance to radionuclide release rates of the detailed composition and behavior of the wastes themselves or of waste and waste product interactions with surrounding geological materials cannot be overemphasized. Predicting the performance of waste sites that contain organics, metals, metalloids and radionuclides for times of 100 to 1,000 yrs or longer must be based on a probability analysis which will reflect increasing uncertainty of performance for longer times. A TSPA modeling approach provides the formal structure on which to hang such a predictive analysis. TSPA calculations also direct the user towards the most important properties of a possible disposal site and the most important reactions, for example that control radionuclide release rates. The public may also be more accepting of performance predictions developed and defended through TSPA (TRW, 1995). The DOE TSPA model is relatively complex. The Electric Power Research Institute (EPRI) has developed a simpler TSPA model which may be adequate for ORIA's purposes (EPRI, 1990).

APPENDIX C - GLOSSARY OF TERMS AND ACRONYMS

AEA	Atomic Energy Act
ANS	American Nuclear Society
ANSI	American National Standards Institute
BIOMASS	Biomass Modeling and Assessment Program, sponsored by the International Atomic Energy Agency and others. It addressees radiological issues associated with accidental and routine releases of radionuclides into the environment, and solid waste management. It covers three themes related to environmental modeling and safety assessment, which are radioactive waste disposal, environmental releases, and biosphere processes.
^{14}C	Carbon-14, an isotope of carbon with an atomic mass of 14 and a half-life of 5715 years
DOE	U.S. Department of Energy (U.S. DOE)
EEC	Environmental Engineering Committee (of the U.S. EPA/SAB/EEC)
EHC	Environmental Health Committee (of the U.S. EPA/SAB/EHC)
EPA	U.S. Environmental Protection Agency (U.S. EPA, EPA, or “the Agency”)
EPRI	Electric Power Research Institute
Fe	Iron (Ferric, Ferrous Oxides)
^{3}H	Tritium (A radioactive isotope of Hydrogen with an atomic mass of 3 and a half-life of 12.5 years)
^{129}I	Iodine-129, an isotope of iodine with an atomic mass of 129 and a half-life of 16 million years
INEEL	Idaho National Engineering Environmental Laboratory
K_d	Distribution/Retardation Coefficient
^{40}K	Potassium, an isotope of potassium with an atomic mass of 40
LAMW	Low Activity Mixed Waste
LAMRW	Low Activity Mixed Radioactive Waste
LDR	Land Disposal Restrictions
LLRW	Low Level Radioactive Waste
LLW	Low Level Waste
m	Meter
Mn	Manganese
NAFTA	National Free Trade Agreement
NCRP	National Council on Radiation Protection and Measurements
NORM	Naturally-Occurring Radioactive Material
Np	Neptunium (A naturally radioactive element with an atomic number of 93. The longest-lived isotope is ^{237}Np)
NRC	U.S. Nuclear Regulatory Commission (U.S. NRC)
NUREG/CR	U.S. Nuclear Regulatory Commission/ Commission Report
ORIA	Office of Radiation and Indoor Air (U.S. EPA)

PATHRAE	Computer code used to assess the maximum annual dose to a critical population group resulting from waste disposal. It is a member of the PRESTO-EPA family of codes and emphasizes two areas: (1) the addition of exposure pathways pertaining to on-site workers during disposal operations, off-site personnel after site closure, and reclaimers and inadvertent intruders after site closure; and (2) the simplification of the sophisticated dynamic submodels to quasi-steady state submodels.
Peak Dose	Highest annual committed effective dose projected to be received by an off-site receptor at a specified location.
PCB	Polychlorinatedbiphenyl
pH	Negative log of hydrogen ion concentration
PRESTO	A family of codes developed to evaluate doses resulting from the disposal of low-activity radioactive waste. These codes include PRESTO-EPA-CPG (assesses annual effective dose equivalents to a critical population group), PRESTO-EPA-DEEP (assesses cumulative population health effects resulting from the disposal of low-activity waste using deep geologic repositories), PRESTO-EPA-BRC (assesses cumulative population health effects to the general population residing in the downstream regional basin as a result of the disposal of low-activity waste in an unregulated sanitary landfill), PRESTO-EPA-POP (assesses cumulative population health effects to the general population residing in the downstream regional basin on a low-level waste site), and PATHRAE (see above).
^{226}Ra	Radium-226, an isotope of radium with an atomic mass of 226 and a half-life of 1,599 years, produced from alpha-decay of thorium-230
RAC	Radiation Advisory Committee (of the U.S. EPA/SAB/RAC)
RCRA	Resource Conservation and Recovery Act, including its various subtitles
SAB	Science Advisory Board (of the U.S. EPA/SAB)
Se	Selinium
SI	International System of Units (System Internationale)
SMI	Shepherd-Miller, Inc.
SWMU	Solid Waste Management Unit
^{90}Sr	Strontium, the strontium isotope with a mass of 90, having a half-life of 28 years
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
^{99}Tc	Technetium (Tc) as an element, or Technetium-99, an isotope of technetium with an atomic mass of 99 and a half-life of 213,000 years
^{230}Th	Thorium, as an element or isotope (e.g., ^{228}Th, ^{230}Th, ^{232}Th, ^{234}Th)
TSCA	Toxic Substances Control Act
TSPA	Total System Performance Assessment
U	Uranium, including the isotopes ^{235}U with an atomic mass of 235 and a half-life of 7.13×10^8 years, and the most common ^{238}U with an atomic mass of 238 and a half-life of 4.51×10^9 years.
U.S.	United States
UZ	Unsaturated Zone

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