United States Environmental Protection Agency | Science Advisory Board (1400A) Washington DC | EPA-SAB-RAC-ADV-01-001 February 2001 *www.epa.gov/sab*

TENORM: EVALUATING OCCURRENCE AND RISKS - AN SAB ADVISORY

A SCIENCE ADVISORY BOARD (SAB) ADVISORY ON EPA'S PROPOSED APPROACH FOR EVALUATING OCCURRENCE AND RISKS OF TECHNOLOGICALLY ENHANCED NATURALLY OCCURRING RADIOACTIVE MATERIAL (TENORM)

February 14, 2001

EPA-SAB-RAC-ADV-01-001

Honorable Christine Todd Whitman
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Re: EPA's Proposed Approach for Evaluating Occurrence and Risks of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) - An SAB Advisory

Dear Ms. Whitman:

At the request of the Office of Radiation and Indoor Air (ORIA), the Radiation Advisory Committee (RAC) of the Science Advisory Board (SAB) reviewed ORIA's proposed approach to evaluating technologically enhanced naturally occurring radioactive material (TENORM) occurrence and risks. The RAC also addressed the issue of whether ORIA is applying this approach appropriately in its technical report for TENORM resulting from uranium mining. The Committee previously reviewed a draft EPA scoping document (*Diffuse NORM Wastes: Waste Characterization and Preliminary Risk Assessment* (RAE-9232/1-2)) addressing this issue and issued a report in 1994 (EPA-SAB-RAC-94-013). ORIA considered the RAC's comments in revising its approach to TENORM, and developed three issue papers for review: a) Issue Paper #1: Proposed EPA Approach to TENORM; b) Issue Paper #2: Proposed Outline for Uranium TENORM Report; and c) Issue paper #3: Proposed TENORM Risk Assessment Methodology.

The RAC held a public meeting in Washington, D.C. on April 25 – 27, 2000, at which it was briefed by, and had technical discussions with, ORIA staff and conducted writing sessions, producing a preliminary draft Advisory. This Advisory addresses the charge questions (see below) as well as issues beyond the charge identified during the public meetings.

In general, the RAC agrees that the general approach to TENORM and the risk assessment methodology are reasonable. The proposed outline for the uranium TENORM Report is adequate. ORIA has done a commendable job in putting these issue papers together.

The RAC had some difficulty responding to the charge questions because ORIA has not clarified what actions might be undertaken as a result of the characterization reports or what types of materials are included in TENORM. In addition, the ORIA apparently has not yet developed detailed adaptations of the relevant models.

The RAC responses to the specific charge questions posed by ORIA are as follows:

a) Question 1: Is ORIA's general approach for characterizing TENORM in a given technical report adequate?

With caution regarding the lack of specificity in regard to the TENORM effort, the answer is conditionally yes. It is reasonable to prepare technical reports on an industry-by-industry basis as each TENORM source can present unique features. Issue Paper #2 lays out a reasonable overview of an appropriate process for accomplishing this goal.

b) Question 2: Has the general approach been appropriately applied in the detailed outline in the second issue paper for uranium mining TENORM?

The outline for uranium mining TENORM is generally adequate; however, approaches that work well for the uranium mining assessment may not transfer easily to other TENORM sectors.

c) Question 3: Is the risk assessment approach, as outlined in the third issue paper, adequate for evaluating risks from uranium mining TENORM? In particular, have the key exposure scenarios been considered?

The approach outlined in the third issue paper is adequate for evaluating the risks from uranium mining TENORM. The list of exposure scenarios given in Issue Paper #2 is extensive and covers most of the important ones except recreational activities (hunting, hiking, fishing, etc.) which in the case of uranium mining, may be the most likely future land use. Also, there are concerns about the lack of peer-reviewed publications regarding use of the Prediction of Radiological Effects due to Shallow Trench Operations models (PRESTO-EPA) for dose/risk assessment. Consequently, the RAC recommends that:

1) the recreational scenario be considered

2) ORIA evaluate PRESTO to determine if it is the best tool to be applied to other TENORM sources

3) morbidity be considered in addition to cancer mortality when final risk estimates are evaluated and presented

The RAC also addressed some issues beyond the charge. First, the RAC recommends that ORIA provide a clear mission statement for the TENORM effort, that it clearly define the kinds of materials included in TENORM, and document the adaptations of the key models. The RAC was unclear about the intended scope of the TENORM documents. They appear to be focused on wastes. The RAC generally supports a broader interpretation, not restricted by interagency boundaries, and recommends that ORIA include products as well as wastes in the TENORM technical documents, based on EPA's mandate to provide guidance to governmental agencies regarding protection of the public from the harmful effects of radiation. The RAC recognizes that this is a policy issue but it is an important consideration in addressing the charge questions. Last, ORIA should review the available data obtained by other program offices such as CERCLA and the regional offices regarding TENORM sources, in particular, uranium mines. The data from these sources could be useful in quantifying the extent of the problem.

The RAC appreciates the opportunity to provide this advisory to you and we hope that it will be helpful in developing EPA's approach to TENORM. We look forward to the response of the Assistant Administrator for Air and Radiation to the comments and recommendations in this report.

Sincerely,

/s/

Dr. William H. Glaze, Chair
Science Advisory Board

/s/

Dr. Janet A. Johnson, Chair
Radiation Advisory Committee
Science Advisory Board

/s/

Dr. Thomas F. Gesell, Chair
TENORM Subcommittee
Radiation Advisory Committee
Science Advisory Board

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ABSTRACT

On April 25 - 27, 2000 the Radiation Advisory Committee (RAC) of the EPA Science Advisory Board (SAB) reviewed three issue papers which describe Office of Radiation and Indoor Air's (ORIAs) approach to Technologically Enhanced Naturally Occurring Radioactive Material (TENORM). Issue Paper #1 describes ORIA's general approach to TENORM; Issue Paper #2 provides a proposed outline for a specific source, uranium mining; and Issue Paper #3 presents the proposed risk assessment methodology. ORIA requested advice on the adequacy of its proposed approach, the application of the approach to uranium mining, as described in Issue Paper #2, and its risk assessment methodology.

The RAC had difficulty responding to the questions posed by ORIA because the intent behind the TENORM effort was not clear. With that reservation, the RAC agrees with ORIA's general approach. However, the RAC recommends that ORIA provide a clear mission statement for the TENORM program and define the types of materials to be included in its TENORM assessments, i.e., wastes only or wastes and products. The RAC supports a broader interpretation of ORIA's mission and recommends that it include products as well as wastes in TENORM assessments. Specific issues of concern include the lack of peer-reviewed publications regarding use of the PRESTO-EPA models for risk assessment, differentiation between variability and uncertainty in the analyses, lack of inclusion of a recreational scenario in the risk assessment, and potential interactions between hazardous materials and radionuclides that may be present in TENORM sources.

KEYWORDS: Technologically Enhanced Naturally Occurring Radioactive Material (TENORM), TENORM, TENORM wastes, TENORM waste products, TENORM sources, TENORM Risks, TENORM Occurrence

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Dr. Donald G. Barnes, Staff Director/Designated Federal Officer, US Environmental Protection Agency Science Advisory Board (1400A),1200 Pennsylvania Avenue, NW, Room 6450, Washington, DC 20460

Ms. Diana Pozun, Program Specialist, US Environmental Protection Agency Science Advisory Board (1400A),1200 Pennsylvania Avenue, NW, Room 6450, Washington, DC 20460

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Dr. Bobby R. Scott, Lovelace Respiratory Research Institute, Albuquerque, NM[2]

Dr. James E. Watson, Jr., Professor, Environmental Science & Engineering Department, University of North Carolina, Chapel Hill, NC

SCIENCE ADVISORY BOARD STAFF

Ms. Melanie Medina-Metzger, Designated Federal Officer, US EPA Science Advisory Board (1400A), US EPA, 1200 Pennsylvania Avenue, NW, Washington, DC 20460

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1 Did not attend meeting of April 25-27, 2000, due to a schedule conflict

2 Did not attend meeting of April 25-27, 2000, but participated in the review

Ms. Diana L. Pozun, Management Assistant, US EPA Science Advisory Board (1400A), US EPA, 1200 Pennsylvania Avenue, NW, Washington, DC 20460

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1. EXECUTIVE SUMMARY

At the request of the EPA's Office of Radiation and Indoor Air (ORIA) the Radiation Advisory Committee (RAC) of the Science Advisory Board (SAB) reviewed three issue papers, which describe ORIA's approach with regard to Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) (EPA, 2000a; 2000b; 2000c). The first paper describes ORIA's approach to TENORM in general. The second paper is a proposed outline for a uranium mining TENORM report. The third paper describes ORIA's proposed risk assessment methodology. The RAC held a public meeting in Washington, D.C. on April 25-27, 2000 at which it was briefed by, and had technical discussions with, ORIA staff, and conducted an editing session producing a preliminary draft Advisory.

ORIA requested the advice of the RAC on the adequacy of its proposed approach to evaluating TENORM occurrence and risks, with specific regard to the approach for characterizing TENORM, the application in the proposed outline for the uranium mining technical report, and the risk assessment approach. In general, the RAC had some difficulty responding to the charge questions because ORIA has not clarified what actions might be undertaken as a result of the characterization reports or what kinds of materials are included in TENORM, i.e., wastes only, building materials, etc. The RAC agrees that the approach to TENORM in general and uranium mine TENORM specifically, as described in the issue papers, is reasonable and notes that ORIA has addressed the comments from its 1994 review (EPA-SAB-RAC-94-013) of the document *Diffuse NORM Wastes: Waste Characterization and Preliminary Risk Assessment (RAE 9232/1-2).*

The specific Charge questions are:

a) Is EPA's general approach for characterizing TENORM in a given technical report adequate?

With the reservations described previously regarding the lack of specificity in the TENORM effort, the answer is conditionally "yes." It is reasonable to prepare technical reports on an industry-by-industry basis, as each can present unique features. Issue Paper #2 provides a reasonable overview of an appropriate process for characterizing uranium mining-related TENORM.

The RAC approves of ORIA's intent to use "best" estimates of parameters for the point estimates and to treat uncertainty and variability with a distributional approach. The RAC has considered ORIA's intent to use best estimates (point estimates) of uncertain parameters for generating best estimates (point estimates) of risk. While recognizing the practicality of this approach, the RAC notes that calculating best estimates of risk considering full variability/uncertainty distributions generally gives a different best estimate of risk than one gets using best estimates of uncertain model parameters. The variability/uncertainty distribution approach is considered more reliable and information on the full risk distribution is generated. Also, the Issue Papers should clearly distinguish variability (true variation from site to site or from person to person) from uncertainty (lack of knowledge about the true value of a parameter for a particular set of conditions).

ORIA's use of the Prediction of Radiological Effects due to Shallow Trench Operations models (PRESTO-EPA) for assessment of risks from uranium mining is reasonable; however the Committee Members who reviewed the literature on PRESTO-EPA felt that the models have not been adequately peer-reviewed.   Models used for regulatory purposes should have a good track record of publication in peer-reviewed journals.

ORIA should assess the applicability of the PRESTO-EPA models to other situations and consider using more appropriate dose/risk assessment tools. The RAC also recommends that the issues of bioavailability, leachability, and radon emanation rates from various sources of TENORM be addressed specifically as suggested by the National Academy of Sciences Committee (NAS 1999).

The time frame and exposure conditions that are the focus of the risk assessment for any TENORM source should be made clear in all documents intended for use by the public. The affected public will be interested in risk estimates applicable to their own exposure histories and should be warned that the prospective risk estimates provided in the TENORM documents may not be applicable to their cases. In view of the uncertainty (and continuing controversy) about the risk of low doses of radiation, the RAC recommends that ORIA provide appropriate disclaimers with the risk estimates it may generate for TENORM sources of exposure.

With regard to characterization of sources, ORIA has only limited success in obtaining information about TENORM quantities and radionuclide concentrations. It appears that voluntary disclosure by the affected parties may not be forthcoming. ORIA should indicate how it intends to fill the data gaps.

b) Charge Question #2: Has the general approach been appropriately applied in the detailed outline in the second issue paper for uranium mining TENORM?

The outline for uranium mining TENORM seems generally adequate. However, approaches that work well for the uranium mining assessment may not transfer easily to other TENORM sectors in which TENORM is emitted to air (e.g., from coal-burning facilities such as electric power plants) or occurs as a product (e.g., in building materials such as concrete blocks). While the proposed outline of the report appears comprehensive, a definitive response to the charge question can be given only after seeing an initial draft with actual data and results of calculations.

In its discussion of uncertainty, it is essential for ORIA to make the distinction between uncertainty and variability, as discussed above. It would also be useful to include a section on "Research Needs" if the uncertainty analysis suggests that additional investigations are required to support any decisions to be made based on the assessment.

The section on "Other Hazardous Constituents" is important and should include a discussion of how these constituents might affect the total radiation risk. When other hazardous constituents can change the characteristics of the TENORM, i.e., to make it more mobile in the environment, affect its toxicity, or change risk in any way, that should be made explicit.

In its outline for uranium TENORM report, ORIA has stated that it will present background radiation and risk information. Because this is an important issue and there are significant variations in background radiation, an explanation of how ORIA plans to determine appropriate radiation background levels is recommended.

It is not clear how far the "radiation overview" (Issue Paper #2, Item VI.A) would be developed. ORIA should consider whether the non-specific radiation primer will dilute the report and whether the entire report should have a lay-level version, either as a separate section, or as a companion volume.

c) Charge question #3: Is the risk assessment approach, as outlined in the third issue paper, adequate for evaluating risks from uranium mining TENORM? In particular, have the key exposure scenarios been considered?

Once more, with reservations regarding specificity, the approach outlined in the third issue paper seems adequate for evaluating the risks from uranium mining TENORM. The lists of exposure scenarios in TENORM Issue Paper #3 (EPA, 2000c) as well as in TENORM Issue Paper #2 (EPA, 2000b) are quite extensive and cover most of the important exposure situations except recreational use. In the case of uranium mines, recreation may be the most likely future land use. The RAC recommends that scenarios that can reasonably be expected to be encountered by a significant number of people should have the highest priority.

While Issue Paper #3 (EPA, 2000c) specifies evaluation of risks from TENORM wastes and products, the emphasis in Issue Paper #2 (EPA, 2000b) seems to be on "disposal." A broader interpretation might be considered. The RAC recommends that ORIA provide a comprehensive discussion of the scope of the analysis, clearly identifying what it covers and what it does not cover.

The RAC's general support of the approach might be strengthened after further review of the documentation for the PRESTO-EPA and MICROSHIELD (a single pathway model designed to calculate external gamma exposure rates from radiation sources of various sizes and shapes) models and ORIA's detailed plans for selection of parameter values and distributions for the uncertainty analysis. As noted previously, the Members of the Committee who reviewed the literature provided by ORIA regarding the PRESTO-EPA models felt that the codes have not been adequately peer-reviewed.

The risk assessment methodology described in Issue Paper #3 is focused on cancer mortality. As it has in past advice to ORIA, the RAC recommends that morbidity be considered in addition to cancer mortality when final risk estimates are made.

The charge questions posed by ORIA and the RAC's responses cover many of the important considerations regarding ORIA's approach to TENORM characterization. However, the RAC also addressed several issues beyond the charge that were identified during the public meetings:

a) The RAC recommends that ORIA provide a clear mission statement for the TENORM effort, that it clearly define the kinds of materials included in TENORM, and document the adaptations of the key models. Also, ORIA should review the available data obtained by other program offices such as the Comprehensive Environmental Response and Liability Act (CERCLA) and the regions regarding TENORM sources, in particular, uranium mines. The data from these sources could be useful in quantifying the extent of the problem. Environmental media concentration data and gamma exposure rate data gathered in support of site-specific risk assessments could be used to validate the models for particular types of sites.

b) In Issue Paper #1, page 10, ORIA proposes to promote and provide education. ORIA should consider as its first educational opportunity scientific societies such as the Conference on Radiation Control Program Directors and the Health Physics Society. Consideration should be given to presentation of papers at meetings and papers in society publications.

c) The RAC supports ORIA's intent to make the TENORM documents useful to a broad audience. The usefulness of the document will be limited if various parts of the risk are left out of the risk assessment because they are regulated by different agencies to differing degrees. The audience will be left with an inaccurate picture consisting of a sum of partial risks derived from different agency risk assessments which are not designed to be aggregated.

d) The RAC was unclear about the intended scope of the TENORM documents. Under the Executive Order 10831 and Reorganization Plan Number 3, EPA is charged with developing Federal Guidance, which is defined as a set of guidelines developed by EPA, for use by Federal and State agencies responsible for protecting the public from the harmful effects of radiation. As it is the EPA's goal to protect the public, the RAC generally supports a broader interpretation not restricted by the interagency boundaries and recommends that ORIA include products as well as wastes in the TENORM technical documents. The RAC recognizes that this is a policy issue but it is an important consideration in addressing the charge questions.

2. INTRODUCTION

2.1 Background

The EPA's Office of Radiation and Indoor Air (ORIA) is formulating its plans for evaluating the occurrence and risks of technologically enhanced naturally occurring radioactive materials (TENORM) and identifying opportunities for abatement. As a part of this process, ORIA has requested that the Radiation Advisory Committee (RAC) review three issue papers, which provide an overview of these plans, and provide the specific approach proposed for uranium mining (EPA, 2000a; 2000b; 2000c). The first paper provides ORIA's intended approach to TENORM. The second paper is a proposed outline for a uranium mining TENORM report. The third paper provides ORIA's proposed methodology for risk assessment as applied to TENORM. The RAC held a public meeting in Washington, D.C. on April 25 - 27, 2000 at which it was briefed by, and had technical discussions with, ORIA staff and conducted an editing session on June 5, 2000 producing a preliminary draft Advisory.

2.2 Charge

The specific charge to the RAC for this review was to respond to the following questions:

a) Is EPA's general approach for characterizing TENORM in a given technical report adequate?

b) Has the general approach been appropriately applied in the detailed outline in the second issue paper for uranium mining TENORM?

c) Is the risk assessment approach, as outlined in the third issue paper, adequate for evaluating risks from uranium mining TENORM? In particular, have the key exposure scenarios been considered?

3. RESPONSE TO THE CHARGE

ORIA requested the advice of the RAC on the adequacy of its proposed approach to evaluating technologically enhanced naturally occurring radioactive material (TENORM) occurrence and risks, specifically with regard to approach for characterizing TENORM, the application in the proposed outline for the uranium mining technical report, and the risk assessment approach. ORIA posed three specific charge questions to the RAC. The questions and the RAC's responses are discussed in detail in this section.

3.1 Is EPA's general approach for characterizing TENORM in a given technical report adequate?

As a general guide for the analysis, the Issue Papers provided to the Committee are reasonable. Because they lack specificity in many areas, the RAC is unable to comment fully on their scientific merits. Documentation of the PRESTO-EPA (Prediction of Radiological Effects due to Shallow Trench Operations) and MICROSHIELD (a single pathway model designed to calculate external gamma exposure rates from radiation sources of various sizes and shapes) model families that will be used to conduct the analysis may help the RAC understand better what will be done, but how parameters will be selected for the models may remain unclear until a draft assessment document is produced.

The RAC notes that ORIA has carefully considered its 1994 comments on the Diffuse NORM Assessment document (EPA-SAB-RAC-94-13) and responded positively to most of them. The RAC also notes that ORIA has changed its strategy for the TENORM characterization from a screening document, designed to differentiate TENORM sources with little potential for health risk from those deserving Agency attention, to a series of descriptive reports covering each of the sources without a prior judgment about the need for abatement. Although ORIA may use indicators of risk as criteria for deciding which sources to investigate first, it intends to use other criteria as well and does not appear to have eliminated any potential TENORM sources from its sphere of interest.

With the caution regarding lack of specificity given above, the answer to the initial Charge question is conditionally "yes." It seems quite reasonable to prepare documents on an industry-by-industry basis, as each can present unique features. The issue paper lays out a reasonable overview of an appropriate process for characterizing TENORM.

3.1.1 Procedural Issues

ORIA has not clarified what actions might be undertaken as a result of the characterization reports. Various types of potential actions might require different data quality objectives. The RAC recommends that ORIA provide a clear mission statement for the TENORM program.

The kinds of materials to be considered TENORM should be clearly delineated. Although in some parts of the issue papers, ORIA mentions TENORM-containing products (e.g., building materials) as proper subjects for evaluation, in other parts only TENORM wastes appear to be considered. The RAC recommends that TENORM be defined clearly. This point is discussed further in Section 4 (Issues Beyond The Charge).

3.1.2 Technical Issues

The RAC has considered ORIA's intent to use best estimates (point estimates) of uncertain parameters for generating best estimates (point estimates) of risk. While recognizing the practicality of this approach, the RAC notes that calculating best estimates of risk considering full variability/uncertainty distributions generally gives a different best estimate of risk than one gets using best estimates of uncertain model parameters. The variability/uncertainty distribution approach is considered more reliable and information on the full risk distribution is generated. In addition, the Issue Papers do not clearly distinguish variability (true variation from site to site or from person to person) from uncertainty (lack of knowledge about the true value of a parameter for a particular set of conditions). Uncertainty can be reduced by research, but inherent variability cannot. Moreover, variability has policy implications regarding risk equity, whereas uncertainty does not (Hattis and Anderson, 1999). The RAC recommends that ORIA clearly separate variability and uncertainty in its distributional analyses, using a two-dimensional Monte Carlo analysis if feasible.

ORIA has proposed to use the PRESTO-EPA models for the analysis of the risks from TENORM in the uranium mining sector. However, the materials provided to the RAC were not clear on whether or not ORIA also intends to make the PRESTO-EPA models its choice for the analysis of other TENORM sectors. Although PRESTO-EPA models may be adequate for the analysis of waste-in-place TENORM sources, such as the waste piles found in uranium mining, they may be inadequate for other TENORM sources in which TENORM is emitted to air (e.g., from coal-burning facilities such as electric power plants) or occurs as a product (e.g., in building materials such as concrete blocks).

The Committee found that the PRESTO-EPA model family has not been adequately peer reviewed. Any model used for regulatory purposes should have a good track record of publication in peer-reviewed journals. Otherwise, members of the public can be subjected to unrealistic regulation at costs that are unjustified. A detailed discussion of this issue is provided in section 3.3 of this report.

It is not clear how ORIA intends to take into account the bioavailability, leachability, and radon emanation rates from various sources of TENORM, as suggested by the National Academy of Sciences Committee charged with conducting the study of TENORM (NAS, 1999). For example, the radon emanation rates for pipe scale differ significantly from the emanation rates for uranium mine waste rock and protore.[1] The RAC recommends that these issues be addressed specifically in future documentation of the TENORM program.

Although the RAC realizes that ORIA's principal focus for TENORM is on assessing risks prospectively in order to judge the need for remedial activities, this focus was not made clear in the materials provided. The time frame and exposure conditions that are the focus of the risk assessment of any TENORM source should be made clear in all documents intended for use by the public. The RAC further notes that the health risk for future exposures to an individual can depend on his or her history of past exposures. The projected risk for a lifetime of exposure for a person born today and residing near the site may be different from that for a current resident who might have experienced higher or lower exposures in the past than suggested by current conditions. The affected public will be interested in risk estimates applicable to their own exposure histories and should be warned that the prospective risk estimates provided in the TENORM documents may not be applicable to their cases.

In view of the uncertainty (and continuing controversy) about the risk of low doses of radiation, the RAC recommends that ORIA provide appropriate disclaimers about any risk estimates it may generate for TENORM sources of exposure. Issue Paper #3 is not entirely clear on the extent to which ORIA will report dose as well as risk estimates in its TENORM assessments. Because dose is one step less controversial than risk, the RAC can support the reporting of both dose and risk, with the proviso that any inconsistencies in conclusions be explained. The RAC Advisory (SAB, 1999) on Federal Guidance Report No. 13 (EPA, 1998) discusses the difficulty of reconciling risk estimates derived via effective dose calculations and direct risk calculations

ORIA has admitted lack of success in obtaining information about TENORM quantities and radionuclide concentrations from various sources. It appears that voluntary disclosure by the affected parties may not be forthcoming. ORIA should indicate how it intends to fill the data gaps.

3.2 Has the general approach been appropriately applied in the detailed outline in the second issue paper for uranium mining TENORM?

3.2.1 Procedural Issues

Again with the reservations about specificity given in the Introduction, the outline for uranium mining TENORM seems generally adequate. ORIA justified its choice of uranium mining for first consideration based on data availability, the number of sites potentially presenting TENORM issues, and concerns by Native American communities. It is not clear whether this group of sources would score high on either a maximum individual or population risk scale. Moreover, uranium mining has a high profile for public perception of radiation risk, while many of the other TENORM sectors do not.

[1] Protore is material that does not meet the grade requirements for economic processing at the time it is removed , but is stored for future use in the event that it becomes economical to mill.

Approaches that work well for the uranium mining assessment may not transfer easily to other TENORM sectors. While the proposed outline of the report appears comprehensive, a definitive response to the charge question can be given only after seeing an initial draft with actual data and results of calculations. With these caveats, the RAC offers the following responses to Charge Question #2.

The RAC notes that the outline does not contain a separate section for either risk characterization or uncertainty analysis, although the section labeled "Summary of Risk Assessment" might be intended to cover the former. Agency guidance for risk assessments suggests that both should be important components of the final report. It is essential for ORIA to make the distinction between uncertainty and variability as discussed above. It would also be useful to include a section on "Research Needs" if the uncertainty analysis suggests that additional investigations are required to support any decisions to be made based on the assessment.

The list of exposure scenarios in Issue Paper #2 is quite extensive and covers most of the important potential exposure situations. However the emphasis in Issue Paper #2 seems to be on "disposal," whereas a broader interpretation might be considered. The RAC recommends that ORIA provide a comprehensive discussion of the scope of the analysis, clearly identifying what it covers and what it does not cover. Inclusion of an "onsite resident and farmer" seems to imply that the assessment would limited to post closure activities unless there have been onsite residents and farmers prior to closure, which seems unlikely.

3.2.2 Technical Issues

In general, there is some confusion about the time scale of the assessment scenarios. ORIA should clarify whether the assessments include projected land uses at some time in the future. It may be possible after some experience is gained to reduce the number of scenarios by eliminating those that do not pose significant individual or population risks. Focusing on a smaller number of land uses would allow more complete analyses of those few critical exposure scenarios. Not all lands are suitable for agriculture or even full time residency. For this reason a scenario for recreational land use should be considered (see Section 3.3 for more detail). The RAC recommends clarification of the scenarios to be assessed and some prioritization based on potential risk.

The RAC recommends that ORIA consider other sources of information on existing mines. The National Institute of Occupational Safety and Health (NIOSH) maintains a computer file of mines measured for the uranium miner epidemiology study. Also the RAC recommends that ORIA clarify the full extent of intended coverage. For example, to what extent is the potential for heap-leach extraction of uranium from materials accumulated in other types of mining (non-uranium) considered? If this practice occurs, would that be included in the uranium mining TENORM report or in another sector report?

The section on "Other Hazardous Constituents" is a worthwhile endeavor, because the greatest risks from a given sector may not be radiological. For example, uranium poses radiological risks but is also a chemical nephrotoxin. Other hazardous materials, such as asbestos and crystalline silica, should be included in the risk analysis. These materials may be of concern primarily during blasting operations at open-pit mines. With regard to risks from impacted water resources, risk assessment by simple comparison to drinking water maximum contaminant levels (MCLs) or other standards may not be as useful as the risk assessment approach for radionuclides because MCLs can contain considerations that are not risk-related, such as feasibility of attainment.

When discussing "other hazardous constituents" that may be present with the TENORM, ORIA should also specify how these constituents might affect the radiation risk. When other hazardous constituents can change the characteristics of the TENORM, to make it more mobile in the environment, or to affect its toxicity or change its risk in any way, that should be made explicit. In the low activity mixed waste advisory, the RAC was concerned with how hazardous components would affect the mobility or volatility of the radioactive component. The same concern applies to the TENORM assessments.

To the extent practicable, ORIA should define the "soil radiation background levels" and surface and groundwater background levels. The National Academy of Sciences Committee that examined the basis for the EPA's TENORM guidance urged EPA to include in its assessment of TENORM-related risks an assessment of existing background radiation and the risks that this radiation contributes to overall risks from radiation exposure. In its proposed outline for uranium TENORM report, ORIA has stated that it will present background radiation and risk information. Since this is an important issue and since there are significant variations in background radiation, an explanation of how ORIA plans to determine appropriate radiation backgrounds is recommended.

The ORIA approach to TENORM characterization calls for a mix of technical reporting (most of the report) and lay-level presentation (VI-A, Radiation Overview). ORIA should consider whether the non-specific radiation primer will dilute the report and whether the entire report should have a lay-level version, either as a separate section, or as a companion volume.

It is not clear how far the "radiation overview" (Issue Paper #2, Item VI.A) would be developed. The focus should be on radiogenic cancer, and possible genetic effects would have to be mentioned, although such have not been observed in humans. It may be desirable also to note the recent information on the possibility of other non-cancer effects (e.g., Shimizu, *et al*., 1999; Ivanov *et al.*, 2000) .

3.3 Is the risk assessment approach, as outlined in the third issue paper, adequate for evaluating risks from uranium mining TENORM? In particular, have the key exposure scenarios been considered?

Once more, with the reservations regarding specificity given in the Introduction, the approach outlined in the third issue paper seems adequate for evaluating the risks from uranium mining TENORM. As mentioned in the response to the second charge question, the list of scenarios is extensive and probably incorporates the highest individual risks but the Uranium Mining Outline (Issue Paper #2) addresses only wastes and not products. However, the RAC offers Table 1 as a suggested approach to systematically defining and communicating the scenarios to be considered. The RAC offers the following detailed responses to Part 3 of the charge.

Table 1. Important exposure pathways for the various exposed individuals or populations

Exposure Pathway	Worker*	On-site Individual	Adjacent Individual	General Population	Rec-reational
Direct gamma	X	X	X	X	X
Inhalation of Rn and decay products	X	X	X	X	X
Inhalation of dust	X	X	X	X	X
Ingestion of soil	X	X	X	X	X
Ingestion of fish	- -	X	X	X	X
Ingestion of food contaminated by dust	- -	X	X	X	- -
Ingestion of food, root uptake from soil	- -	X	X	X	- -
Ingestion of drinking water, well	- -	X	X	- -	- -
Ingestion of food contaminated by well water	- -	X	X	- -	- -
Radiation from TENORM in pipes as structural supports in homes	- -	- -	X	- -	- -
Radiation from TENORM in road pavement & aggregate	- -	- -	X	- -	- -
Radiation from TENORM in bldg materials	- -	- -	X	- -	- -
Ingestion of river sediments	- -	- -	- -	X	- -
Ingestion of river water, ground water pathway	- -	- -	- -	X	- -
Ingestion of river water, runoff pathway	- -	- -	- -	X	- -
Ingestion of food contaminated by river water	- -	- -	- -	X	- -
Ingestion of surface water	- -	- -	- -	- -	X

*It is important to note that a worker may also be exposed to radiation from TENORM as an on-site or adjacent resident.

3.3.1 Risk Assessments

The RAC recommends that ORIA provide more detail on how risk assessments will be approached, discuss the impact of the choice of model, and indicate whether site-specific risk will be calculated for each case study. It is not clear from the third Issue Paper how far into the future the doses and risks will be projected. ORIA should consider whether the appropriate time horizon should be the same for all TENORM sources. The scenarios to be included are strongly dependent upon the time frame of the study.

As noted previously, the contribution to risk from hazardous constituents other than radionuclides should be calculated. ORIA should consider whether there will be enough information to determine risk from the other, non-radioactive, hazardous constituents as well as the radiation risk. The radiation risk may not be the limiting factor (most risk) in all cases.

In several places, ORIA indicates that it will estimate maximum individual risk, but the concept of "maximum" is not well defined. Hypothetical exposure scenarios that are possible but unlikely can lead to risk estimates many times higher than those likely to be experienced by real individuals. The RAC recommends limiting the analysis to scenarios that can reasonably be expected to be encountered by a significant number of people. Perhaps the principal focus should be on the 5-95 percentile range without reporting the "maximum" and "minimum" values from the Monte Carlo analyses. Such approach seems to be implied by ORIA's response to the RAC recommendations regarding issue 5 (page 11 of the issue paper).

The RAC recommends that ORIA consider morbidity risk in addition to cancer mortality when final risk estimates are made. The RAC notes that it has made this recommendation in several previous contexts. The RAC also notes that publications associating non-cancer morbidity with radiation have appeared very recently in the in the literature (Shimizu, et al., 1999; Ivanov *et al*., 2000).

The materials that are "TENORM" for the uranium-mining industry according to ORIA's policy should be clearly specified in this document. Materials that might cause risk to the public, but which are not included in this assessment, should also be clearly identified with at least a qualitative statement of how the assessed and un-assessed sources might differ in terms of risk to the public. The RAC also recommends that the risk assessment approach consider the end user of recycled products.

3.3.2 Models

ORIA has proposed to use the PRESTO-EPA models as its multimedia modeling tool for the analysis of the risks from TENORM in the uranium mining sector. EPA developed the PRESTO-EPA family of computer codes to aid in developing standards for disposing of low-level radioactive waste. The PRESTO-EPA-CPG and PRESTO-EPA-POP models have been used to generate dose/risk estimates to support: (1) the proposed Low-level Radioactive Waste Rule (1987); (2) the proposed Low Activity Mixed Waste Rule (1998); and (3) the draft Naturally Occurring Radioactive Materials Report.

The materials provided to the RAC were not clear on whether or not ORIA also intends to make the PRESTO-EPA model family its choice for the analysis of TENORM sources other than uranium mine wastes. Although PRESTO-EPA models may be adequate for the analysis of waste-in-place TENORM sources, such as the waste piles found in uranium mining, they may be inadequate for other TENORM sources from which TENORM is emitted to air (e.g., from coal-burning facilities such as electric powerplants) or occurs as a product (e.g., in building materials such as concrete blocks).

The Committee did not find sufficient evidence that the PRESTO-EPA model family had been adequately peer-reviewed or that the basic structure and features of the model had been published in a peer-reviewed journal. It appears that the most recent extensive peer review of the PRESTO-EPA models was carried out in 1984. Since that time, considerable new knowledge has been gained related to radiation risk assessment for radionuclide contaminated media, and the capability of modeling radionuclide movement through various media has been improved significantly. However, there is no evidence in the material provided to the RAC that PRESTO-EPA models have been critically reviewed in light of this new knowledge and whether any attempt has been made to include model parameter uncertainty in risk assessment with PRESTO-EPA models. The proposal to link the PRESTO-EPA models with the @RISK (a multi-variance uncertainty model) to handle uncertainty analysis may be adequate to evaluate uncertainty, but the RAC was not provided with any evidence that this technique has been successfully implemented.

It is unclear whether components of the PRESTO-EPA models have been evaluated to see whether they actually model the process they represent in a scientifically valid way. This comment relates to the possibility that inappropriate component models may be incorporated into the PRESTO-EPA models. In 1983, a quality assurance audit was conducted related to the PRESTO-EPA models by Inter Systems, Inc (ISI). However, they state in their final report (ISI, 1983) that:

> "ISI only considered the coding of the equations and the logic presented in the documentation package."

> "No assessment of the appropriateness of equations used to simulate processes was made."

Recently, additional improvements have been made in PRESTO-EPA model family. Based on information provided to us, it appears that PRESTO-EPA-POP has been replaced by PRESTO-EPA-CLNPOP. Also PRESTO-EPA-CPG has been replaced by PRESTO-EPA-CLNCPG. Model applicability has been expanded to include in addition to radioactive waste disposal, soil cleanup, agricultural land application, land reclamation, accidental spills, in addition to combining PRESTO-EPA-CPG and PRESTO-EPA-POP into a common system. Thus, the need for peer review applies to the new models, and it is unclear whether the changes have been subjected to peer review by experts. The Members of the RAC have not seen a single publication concerning the workings and details of the PRESTO models in a peer-reviewed journal. If there have been no peer-reviewed publications, the appropriateness of the new models for their intended use cannot be adequately evaluated based on presently available information.

A non-peer reviewed paper, presented at the Waste Management 97 conference, compared PRESTO-EPA predictions with real data. The report (Rogers *et al.*, 1997) stated that the methodology used in PRESTO-EPA-CLNCPG and PRESTO-EPA-CLNPOP is less conservative and more realistic than that used in Residual Radioactive Materials Guidelines (the Department of Energy model RESRAD). This was based on comparing predicted and observed radionuclide concentrations in well water at the Savannah River facility for radionuclides transported to the well from a nearby burial site. However, what was not stated was that for two thirds of the cases evaluated, model predictions based on the PRESTO models were orders of magnitude in error. For tritium, PRESTO-EPA-CLNCPG over-predicted by a factor of 2.4; for Tc-99 the over prediction was a factor of 435. PRESTO-EPA-CLNCPG under predicted concentrations of I-129 by a factor of 260. The purpose of the evaluation, reported in this paper, was to compare the performance of the PRESTO models to the performance of the RESRAD code. The PRESTO-EPA-CLNCPG predictions were closer to measured values than the RESRAD predictions. However, given the magnitude of the difference between the concentrations calculated by PRESTO-EPA-CLNCPG and the measured concentrations, ORIA should carefully assess the applicability of PRESTO to all TENORM sources. The RAC also encourages additional comparisons between the models and field data when feasible.

A second paper provided to the RAC by ORIA presents a comparison of results from PRESTO and MMSOILS (a multi-media contaminant transport, fate, and exposure model for soils) in which the results differed by about an order of magnitude (Mills *et al.*, 1999).

While the RAC recognizes that the use of PRESTO in the context of evaluation of TENORM does not have a regulatory purpose, any model used for such purposes should have a good track record of publication in peer-reviewed journals. Otherwise, members of the public can be subjected to unrealistic regulation at costs that are unjustified. ORIA should consider using more appropriate modeling tools for emissions to air.

3.3.3 Exposure Scenarios

The risk assessment approach should specifically include recreational use and resident and non-resident rancher exposure scenarios. Many uranium mining facilities are located in remote areas not suitable for farming. These areas are most likely to be used in the future for recreational purposes and stock grazing. The RAC recommends including diverse recreational scenarios such as hunting, hiking, fishing, golf, hiking, camping, mountain biking, motorcycling, snowmobiling, all terrain vehicle (ATV) use, etc. in its risk analyses. In addition to direct exposures to recreationists, ORIA should consider impacts such as erosion and resuspension from ATV and other off-road vehicle use, and the effect of creating an irrigated golf course on the rates of contaminant transport to ground water. Assessing risks based only on a resident or even a non-resident farming scenario may result in an unreasonable estimate of potential future risks.

While the PRESTO-EPA models may not specifically deal with the recreational scenario, at least for uranium mining, recreation may need to be considered using a manual approach. It is not sufficient to simply adjust the residence times to account for a transient population. Pathways such as direct gamma exposure, ingestion of surface water, radon decay product inhalation, and ingestion of fish will have different exposure conditions from those assumed for the resident and non-resident farmer.

3.3.4 Case Studies

In Case Studies, some unique pathways are discussed. Some of them are not generally applicable. For instance, in the Orphan Mine in the Grand Canyon, the exposure pathway of tourists drinking from the spring containing contaminated water is mentioned. In this case, a risk should be calculated for a transient population.

3.3.5 ^{232}Th and its Decay Products

ORIA should address potential exposure to ^{232}Th and its decay products in the technical report for uranium mining. While, in general, natural thorium concentrations are in the range of background, in uranium mineralized areas (NCRP, 1993) this may not be the case in some specific situations. The radon species to be studied might include ^{220}Rn, because some ore bodies contain substantial amounts of ^{232}Th. Although this radon isotope has a short half life, some of its progeny have much longer half lives; ^{220}Rn might be of significance given high enough concentrations of its ^{232}Th parent in ore bodies or overburden piles.

3.3.6 Direct Gamma Exposure

The RAC recommends that ORIA clarify what is meant by “direct gamma exposure.” Depending upon location, the most significant source might be direct radiation and skyshine from overburden piles. In other situations, direct gamma exposure might include external gamma exposure from contaminated particles that have been suspended from sources and deposited in the vicinity of the individuals’ homes. The latter source of exposure might be important over the long term.

3.3.7 Resuspension

The treatment of resuspension in the PRESTO-EPA models utilizes variations of the resuspension-factor approach, which is a time-dependent factor applied to the deposition density of a radionuclide. However, this approach was developed for application to fresh deposits of radionuclides on a soil surface and includes the effect of the deposited material weathering into the soil surface. This approach is not appropriate for a source that is mixed throughout a soil volume, such as a waste pile. In the latter case, the mass-loading approach is more appropriate wherein the mass of particles in the air is assumed to be derived solely from the contaminated soil. A default value of 100 micrograms per cubic meter is frequently assumed, although a site-specific measured long-term average value can be used. Also, an enhancement factor is frequently used, where the contaminant is assumed to be more concentrated on the small re-suspended particles compared to the bulk mass of the soil. Values of the enhancement factor might vary from 1 to 5. Thus, the predicted concentration of a radionuclide above the soil surface is:

$C_a = K\ E\ M\ C_s$ where

- C_a = Concentration of radionuclide in air, pCi per cubic meter;
- K = Units-conversion factor, 1E-6 g per micro-g;
- E = Enhancement factor, unitless;
- M = Mass loading, micro-g per cubic meter; and
- C_s = Concentration of radionuclide in soil, pCi per g.

3.3.8 Uncertainty Analysis

The RAC notes that ORIA apparently intends to use only 1000 iterations of the Monte Carlo simulation in its uncertainty analysis. While this number could well be sufficient for ORIA's purposes, it might be wise to investigate convergence before limiting the target number of iterations.

4. ISSUES BEYOND THE CHARGE

ORIA's approach to TENORM issues is comprehensive and, after incorporating the RAC recommendations in response to the charge questions, will provide a reasonable estimate of the occurrence and risks. Several issues beyond the charge merit consideration by ORIA.

4.1 Intended Scope of the TENORM Documents

The RAC was unclear about the intended scope of the TENORM documents. Under the Executive Order 10831 and Reorganization Plan Number 3, EPA is charged with developing Federal Guidance. Federal Guidance is defined as a set of guidelines developed by EPA, for use by Federal and State agencies responsible for protecting the public from the harmful effects of radiation. Federal guidance helps protect both the general public and the people who work with and around radiation every day. Technical Reports that provide current scientific and technical information for radiation dose and risk assessment can be considered federal guidance. Since these guidance documents are not regulations, they are not legally enforceable. Federal and State agencies have the authority to determine the details of their own regulations within the scope of their authority.

As it is the EPA's goal to protect the public, the RAC generally supports a broader interpretation not restricted by the interagency boundaries and recommends that ORIA include products as well as wastes in the TENORM technical documents. ***While this recommendation reaches into the realm of policy, not generally addressed by the RAC, several Members of the Committee felt that it is important to raise it in the Advisory on TENORM.*** The RAC also recommends that ORIA consider avoiding the emphasis on TENORM wastes. EPA has done a notable job of promoting pollution prevention and encouraging people to "reduce, reuse, and recycle." With sustainability as the goal, the newest industrial parks are designed for the byproducts of one industry to directly flow to another industry as raw materials. Examples of TENORM materials that can be considered "waste" to one industry, but "feed material" to another industry include 11e(2) material[2], slag from rare earth mineral extraction, and sewage sludge. The 11e(2) material is sold as feed material for uranium processing. The sewage sludge is sold to farmers as a soil conditioner. The slag from rare earth mineral extraction is sold as "ladle cover" for smelting, and then the smelting industry slag is ground up and added to concrete in cinder blocks to add strength.

The U.S. Nuclear Regulatory Commission (NRC) Report Radiological Assessments for Clearance of Equipment and Materials from Nuclear Facilities (referred to as NUREG 1640) (NRC,

[2]The term "11e(2) material" is used as shorthand for uranium or thorium mill tailings and refers to the section in the Atomic Energy Act where they are defined. The specific definition is "the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content."

1999) discusses possible scenarios for the use of slag in Appendix J. These include the use of steel industry slag in basement construction as an aggregate in the concrete block, the use of slag in a roadbed, and the disposal of slag at a landfill. The RAC believes that the type of comprehensive approach used for following radionuclides in NUREG 1640 is the approach necessary to give an accurate picture of risk. Without commenting on the content of NUREG 1640, the approach used followed radionuclides through various processes in products and in "wastes" while considering exposures to workers and to the public.

Issue Paper #2 discusses TENORM "waste" and mentions that the report will focus on TENORM from both overburden and evaporation ponds. The use of the term "waste" and the suggested focus seem to imply that the full range of risks would not be assessed. The actual intent of the report in this regard should be clarified. The public might gain a better appreciation of the importance of TENORM relative to already regulated radioactive materials if the analysis included a characterization and risk assessment of all sources of radiation associated with a given facility or product. For an operating open-pit mine (and perhaps associated mill), for example, the analysis could include the release of radon and soil borne materials by blasting, the loading and transport of ore and overburden, any on-site milling and beneficiation, and releases of radon from stockpiled ore and finished product.

The RAC notes that some of the non-waste sources may be relatively important. For example, the radionuclides in coal-fired power plant emissions, which could be considered to be TENORM, may well result in some risk. The radiological risks from coal-fired and nuclear power plants are about the same, depending on the age and type of power plants, both coal-fired and nuclear (UNSCEAR, 1993).

Although the RAC realizes that ORIA's principal focus for TENORM is on assessing risks prospectively in order to judge the need for prevention or remedial activities, this focus was not made clear in the materials provided. The time frame and exposure conditions that are the focus of the risk assessment of any TENORM source should be made clear in any document intended for use by the public. The RAC further notes that the risk to an individual can depend on his or her past exposures as well as future exposures. The projected risk for a lifetime of exposure for a person born today and residing near the site may be different from that for a current resident who might have experienced higher or lower exposures in the past than suggested by current conditions. The affected public will be interested in risk estimates applicable to their own exposure histories and should be warned that the prospective risk estimates provided in the TENORM documents may not be applicable to their cases.

4.2 Use of Existing Data from Other Programs Within EPA

ORIA should review the available data obtained by other program offices such as CERCLA and the regional offices regarding TENORM sources, in particular, uranium mines. The data from these sources could be useful in quantifying the extent of the problem. Environmental media concentration data and gamma exposure rate data gathered in support of site-specific risk assessments could be used to validate the models for particular types of sites.

4.3 Background Evaluation for TENORM Sites

Any evaluation of background at TENORM sites should take into account not just average soil background radionuclide concentrations but also background variability within localized areas. Uranium mines, by necessity, are located in mineralized areas that may have un-mined outcrops of relatively high grade ore and several different soil types with varying radionuclide concentrations. These areas are representative of local background conditions and can contribute significantly to background radiation doses.

4.4 Education and Risk Communication

In Issue Paper #1, page 10, ORIA proposes to promote and provide education and guidance for safely and economically cleaning up and disposing of TENORM Wastes. ORIA should consider as its first educational opportunity scientific societies such as the Conference on Radiation Control Program Directors and the Health Physics Society. Consideration should be given to presentation of papers at meetings and papers in society publications.

In the ORIA presentation to the RAC regarding the Uranium TENORM Report, it was pointed out that of the 4,000 plus mines, approximately 1,000 are on Tribal lands. It is important that ORIA communicate risk assessment plans with <u>all</u> of the affected tribes in advance of the study. Dedicated efforts need to be developed to involve the tribes in providing input for the pathway calculations. It is well known that Native Americans have some living habits and ingestion patterns that differ from other American population groups.

The RAC supports ORIA's intent to make the TENORM documents useful to a broad audience. The usefulness of the document will be limited if various parts of the risk are left out of the risk assessment because they are regulated by different agencies to differing degrees. The audience will be left with an inaccurate picture consisting of a sum of partial risks derived from different agency risk assessments which are not designed to be aggregated.

5. SPECIFIC COMMENTS BY COMMITTEE PARTICIPANTS

General: Several references may be useful in developing the TENORM technical reports, specifically NCRP Report No. 118, “Radiation Protection in the Mineral Extraction Industry”, and a book written in the 1950s titled “Uranium Country”.

Issue Paper #2, Pg 11, VII. B. Methodology and Techniques, 2nd paragraph: Mentions EIA (Energy Information Agency of DOE) compiling reclamation cost information on uranium recovery facilities. Presumably this includes side-stream extraction, and overlaps with U-milling. Is this to be included in the report, or was it just mentioned in passing?

Issue Paper #3, Pg 5 para 1: States that “these distributions will not be meant to represent actual or expected parameter value distributions.” Why not?

Issue Paper #3, Pg ,5 Second to last sentence: “The maximum values will then be calculated and returned to @RISK.” This is not clear. Isn’t this technique used to avoid the bias associated with presenting maximum values? Aren’t frequency distributions reported and then the user can see central tendency as well as various percentiles?

Issue Paper #3, Dose and Risk Factors (pg 9, 3rd full paragraph): Ingestion and inhalation dose conversion factors from FGR-11. Risk conversion factors from FGR-13. Isn’t this using two different generations of ICRP dosimetry?

Issue Paper #3: How will radon emanation rates be determined?

APPENDIX A- GLOSSARY OF TERMS AND ACRONYMS

ATV	All Terrain Vehicle
@RISK	A multi-variance uncertainty model. This is the code that employs sampling techniques to generate outputs as statistical distributions rather than single point values
C_a	Concentration of radionuclide in air, pCi per cubic meter
CERCLA	Comprehensive Environmental Response and Liability Act
Ci	Curies (3.7×10^{10} disintegration per second)
C_s	Concentration of radionuclide in soil, pCi per g
CPG	Critical Population Group
DOE	U.S. Department of Energy
E	Enhancement factor, unitless
E	Exponent (e.g. 1E-6 = 10^{-6})
EPA	U.S. Environmental Protection Agency (U.S. EPA, or "The Agency")
g	Gram
I-129	Iodine-129. As an unstable radioactive isotope of iodine. Iodine 129 is produced naturally in the upper atmosphere and also produced in nuclear explosions. In addition, iodine 129 is released at very low levels into the environment from facilities that separate and reprocess nuclear reactor fuels, and from waste storage facilities.
ICRP	International Commission on Radiological Protection
ISI	Inter Systems, Inc.
K	Units-conversion factor, 1E-6 g per micro-g
M	Mass loading, micro-g per cubic meter
micro	: ,[10^{-6}] in combination with specific units
MCLs	Maximum Contaminant Levels
MicroShield	The MicroShield model is a single pathway model designed to calculate external gamma exposure rates from radiation sources of various sizes and shapes (Grove 1996). The model utilizes either analytical expressions and numerical integration to calculate the gamma exposure rate at a point near the radiation source. MICROSHIELD has the capability to model 16 different source and shield configurations, including point, line, plane, and disk sources, rectangular slabs, cylinders, and spheres.
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute of Occupational Safety and Health
NORM	Naturally-Occurring Radioactive Material
NRC	Nuclear Regulatory Commission
ORIA	Office of Radiation and Indoor Air (U.S. EPA)
p	pico-, [10^{-12}] in combination with specific units

PRESTO	Prediction of Radiological Effects due to Shallow Trench Operations. A family of codes developed to evaluate doses resulting from the disposal of low-level 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-level 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-level waste in an unregulated sanitary landfill),and PRESTO-EPA-POP (assesses cumulative population health effects to the general population residing in the downstream regional basin on a low-level waste site)
PRESTO-EPA-CLNCPG	The PRESTO-CLNCPG model (RAE 1999) was developed by EPA for evaluating contaminated soil sites. The computer code is a modified and extended version of the PRESTO-CPG model for low-level waste site analyses. The model predicts the maximum annual committed effective dose to a critical population group living on a contaminated soil site or a near surface low-level radioactive waste disposal facility. The exposure pathways to the critical population group include: Groundwater transport to a well, erosion and runoff to surface water, external radiation, production of vegetables, milk, and meat on contaminated soil, dust inhalation, Radon gas inhalation, inadvertent ingestion of soil, and consumption of fish.
PRESTO-EPA-CLNPOP	The computer code is a modified and extended version of the PRESTO-POP model to include the onsite resident scenario.
RAC	Radiation Advisory Committee (U.S. EPA/SAB/RAC)
RESRAD	Residual Radioactive Materials Guidelines (The DOE Model). This is a computer code developed by DOE to implement its guidelines for deriving guidelines for allowable concentrations of residual radioactive material in soil.
Rn	Radon, as an element or as an isotope of thorium or uranium alpha-decay chains (e.g., ^{219}Rn, ^{220}Rn, ^{222} Rn)
SAB	Science Advisory Board (U.S. EPA)
Tc-99	Technetium-99. Technetium-99 is predominantly an artificially produced, silver-gray, radioactive metal, occurring naturally only in very small amounts in the earth's crust. Tc-99 was first obtained from molybdenum but is also produced as a nuclear reactor fission product of uranium and plutonium.
TENORM	Technologically Enhanced Naturally Occurring Radioactive Materials
Tritium	a form of hydrogen that is radioactive, and like hydrogen it reacts with oxygen to form

water. Tritium is produced naturally in the upper atmosphere when cosmic rays strike air molecules. Tritium can also be produced by man during nuclear weapon explosions, in reactors intended to produce tritium for nuclear weapons, and by reactors producing electricity.

Th	Thorium, as an element or as an isotope (e.g., ^{228}Th, ^{230}Th, ^{232}Th, ^{234}Th)
U	Uranium, as an element or as an isotope (e.g., ^{234}U, ^{235}U, ^{238}U)
Uncertainty	Lack of knowledge about the true value of a parameter for a particular set of conditions
Uncertainty Analysis	Refers to the study of the uncertainty of the model outputs as a function of parameter and data uncertainties
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
Variability	Variation from site to site or from person to person

REFERENCES

Chen, S.Y., LePoire, D.J., Arnish, J.A., Faillace, E., Kamboj, S.K., and B. Wharry. 1998. MILDOS-AREA User's Guide MILDOS-AREA User's Environmental Assessment Division, Argonne National Laboratory, Argonne, IL (http://web.ead.anl.gov/mildos/usersguide.pdf)

EPA. (U.S. Environmental Protection Agency, Office of Radiation and Indoor Air). 2000a. Issue Paper #1 - Proposed EPA Approach to TENORM). U.S. Environmental Protection Agency, Washington, DC.

EPA (U.S. Environmental Protection Agency, Office of Radiation and Indoor Air). 2000b. Issue Paper #2 - Proposed Outline for Uranium TENORM Report. U.S. Environmental Protection Agency, Washington, DC.

EPA (U.S. Environmental Protection Agency, Office of Radiation and Indoor Air). 2000c. Issue Paper #3 - Proposed TENORM Risk Assessment Methodology. U.S. Environmental Protection Agency, Washington, DC.

EPA (U.S. Environmental Protection Agency, Office of Air and Radiation). 1998. Health Risks from Low-Level Environmental Exposure to Radionuclides, Federal Guidance Report No. 13 - Part 1, Interim Version (EPA 402-R-97-014).

Grove Engineering. 1996. MICROSHIELD, Version 5, User's Manual. Grove Engineering, Rockville MD.

Hattis, D. and E. Anderson. 1999. What should be the implications of uncertainty, variability and inherent "biases"/"conservatism" for risk management decision-making? *Risk Analysis* 19 95-107.

ISI (Inter Systems, Inc). 1983. PRESTO-EPA Quality Assurance Audit. A report generated for the Environmental Protection Agency by Inter Systems, Inc.

Ivanov, V. K.; Maksioutov, M. A., Chekin, S. Yu.; Kruglova, Z. G.; Petrov, A. V., and A.F. Tsyb. 2000. Radiation-epidemiological analysis of incidence of non-cancer diseases among the Chernobyl liquidators. *Health Phys*. 78:495-501.

Mills, W.B., Lew, C.S, and C.Y. Hung. 1999. Sensitivity of Concentration and Risk Predictions in the PRESTO and MMSOILS Multimedia Models: Regression Technique Assessment. *Risk Analysis* 19 511-525. 1999

NAS/NRC (National Academy of Science/National Research Council). 1999. Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials. Report of the National Research Council. National Academy Press. Washington, DC.

NRC (U.S. Nuclear Regulatory Commission). 1999. Radiological Assessments for Clearance of Equipment and Materials from Nuclear Facilities (NUREG-1640 Vol. 1 &Vol. 2) Draft Report for Comment, March 1999.

NCRP (National Council on Radiation Protection and Measurements). 1993. Radiation Protection in the Mineral Extraction Industry. Bethesda, MD, USA.

Rogers, V.C. 1997. Approaches for Modeling Components of Performance Assessment. Presentation at the US Department of Energy Low-Level Radioactive Waste Management Conference. Salt Lake City, UT, USA.

SAB (Science Advisory Board). 1999. Radiation Advisory Committee (RAC). Review of Health Risks From Low-Level Environmental Exposures to Radionuclides (FGR-13 REPORT). EPA-SAB-RAC-99-009.

SAB (Science Advisory Board). 1994. SAB Radiation Advisory Committee (RAC). Review of Diffuse NORM Draft Scoping Document. EPA-SAB-RAC-94-013.

Shimizu, Y., Pierce, D. A., Preston, D. L., and K. Mabuchi. 1999. Studies of the mortality of atomic bomb survivors. Report 12, Part II. Noncancer mortality: 1950-1990. *Radiat. Res*. 152:374-389.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). 1993. Sources and effects of ionizing radiation. UNSCEAR 1993 report to the General Assembly, with scientific annexes. United Nations, New York, NY.