CONSIDERATIONS FOR GUIDANCE FOR RADIOACTIVE WASTE DISPOSAL ARISING FROM RULES UNDER 40 CFR 191 AND 40 CFR 194

Kathleen M. Trauth and Sharla G. Bertram
Sandia National Laboratories

Bryan Bower
USDOE

ABSTRACT

Preliminary performance assessments have been conducted for the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico. These analyses assess the ability of the WIPP, a proposed disposal facility for defense-generated nuclear waste, to comply with the Environmental Protection Agency's (EPA's) requirements at 40 CFR 191. With the passage of the WIPP Land Withdrawal Act in 1992, the EPA is required to develop WIPP-specific criteria (to be found at 40 CFR 194) by which the EPA will certify whether or not the WIPP complies with 40 CFR 191. The preliminary performance assessments, including expert judgment panels on future societies and passive institutional controls, are a useful source of information that can be used to guide the EPA in its development of the criteria. Three areas that would benefit from consideration by the EPA are future states, passive institutional controls, and groundwater requirements.

INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) is a research and development facility to demonstrate the safe disposal of transuranic (TRU) waste generated by the U.S. Department of Energy (DOE) defense programs. Before permanently disposing of TRU waste at the WIPP, the DOE must demonstrate compliance with applicable long-term disposal standards of the Environmental Protection Agency (EPA). These disposal standards have been promulgated at 40 CFR Part 191, Subparts B and C (1,2). Performance assessment forms the basis of the evaluation of compliance with these standards.

Subparts B and C of 40 CFR 191 contain four main provisions related to disposal of radioactive waste in a repository. First, in Subpart B, performance assessment analyses attempt to indicate expected performance of a disposal system for 10,000 years and compare calculated radionuclide releases to probabilistic radionuclide release limits found in § 191.13. Second, the Assurance Requirements, found in § 191.14, indicate supplementary actions (e.g., markers, records, monitoring) to be taken to account for the uncertainties in the conduct of analyses of a disposal system over the regulatory period (10,000 years). Third, the radionuclide doses that individuals may receive from an undisturbed disposal system are limited for 10,000 years in § 191.15. Fourth, Subpart C incorporates the requirements of the National Primary Drinking Water Regulations (40 CFR 141.15 and 141.16) (3) to protect underground sources of drinking water (USDWs) from radionuclide contamination from an undisturbed disposal system for 10,000 years (§ 191.24).

NEED FOR ADDITIONAL GUIDANCE

The repromulgation in 1993 of 40 CFR 191 addressed problems that arose from a 1987 court decision (4). Both the repromulgated rule and the parts of the 1985 Final Rule still in effect require further guidance from EPA for appropriate implementation. As required by the passage of the WIPP Land Withdrawal Act (WIPP LWA) in 1992 (5), the EPA is developing WIPP-specific criteria (to be found at 40 CFR 194) by which the EPA will certify whether or not the WIPP complies with 40 CFR 191. While it may not be appropriate to place guidance for the general rule in WIPP-specific criteria, guidance is necessary regardless of its form.

Experience from performing preliminary performance assessments for the WIPP (6,7,8), including the use of expert judgment panels on future societies and passive institutional controls (9), has provided information related to three compliance areas: 1) guidance on future states of society and the biosphere, 2) guidance on implementing passive institutional controls, and 3) guidance on complying with groundwater requirements. These areas would apply to all repositories (unless specifically exempted) and would benefit from consideration by the EPA during its development of new criteria.

GUIDANCE ON FUTURE STATES OF SOCIETY AND THE BIOSPHERE

The EPA has proposed to define future states for the WIPP in 40 CFR 194. The purpose of these assumptions would be to reduce both unnecessary speculation and uncertainty in compliance assessments. These assumptions will be necessary for WIPP and for any future nuclear waste repositories regulated by 40 CFR 191.

Some concerns are inherent in specifying future state assumptions. Prescriptive assumptions (not allowing for flexibility based on site-specific conditions) could lead to conducting analyses of a site for which the required assumptions are inappropriate. Some examples could be assumptions of future population growth, climate, seismicity, and natural resources use and technology. Non-prescriptive future state assumptions based on current conditions will avoid the inadvertent specification of future-state-related siting criteria. Such assumptions implemented on a site-by-site basis would provide flexibility to formulate adequate and appropriate criteria for each repository. Future conditions assumed to be the same as current conditions will provide sufficient basis for reliably warning future societies about the contents of the repository and the consequences of intrusion.

Disturbed Performance (Human Intrusion)

Guidance provided in 1985 by the EPA in Appendix B (Appendix C in the 1993 rule) to 40 CFR 191 focused on the effects of human intrusion on geologic repositories for radioactive waste disposal. At that time, the EPA indicated that human intrusion was expected to be only one of many potentially significant factors affecting repository performance. Since that time, the EPA has focused attention on future states

and human intrusion assumptions, as indicated in discussions with its National Advisory Council on Environmental Policy and Technology (NACEPT) Subcommittee on the Waste Isolation *Pilot Plant* during a September 22-23, 1993 meeting (10). The EPA's emphasis on issues related to human intrusion, along with preliminary performance assessments conducted for the Waste Isolation Pilot Plant, strongly indicate that human intrusion can be the most significant release scenario for a well-sited repository. The guidance in Appendix C has become a driver in determining how the WIPP performance assessment will be conducted.

Assumptions must be made about future states of society to establish parameters for evaluating the impacts of inadvertent, intermittent exploratory drilling into the repository (40 CFR 191.13, Containment Requirements). Certain of these parameters (related to the intensity of future drilling and borehole fill permeability) have been shown to be significant sources of uncertainty for the WIPP performance assessment. Because these parameter values are unknowable, and because they can dominate the results of the performance assessment, bounds must be placed on the assumptions. This bounding could be accomplished by specifying that the drilling technology will be the same as today and the drilling intensity over time will be appropriate for exploitation of resources utilized by today's society, taking into consideration the rate of exhaustion of those resources and the effectiveness of both active and passive institutional controls. Such specification of future states assumptions would eliminate these uncertainties from the analyses.

The EPA has long recognized the difficulty and inappropriateness of trying to project precisely the actual risks of releases because of likely changes in population distributions, food chains, living habits, and technological capabilities (11,12,13,1). The EPA has also recognized that the effects of intrusion of a repository by humans are an important source of uncertainties in performance assessments (1).

According to the WIPP 1992 performance assessment (14), the rate of future drilling activity is one of the most important parameters because it affects all releases, regardless of the barrier components considered. Uncertainty in borehole-fill permeability is also one of the most important contributors to total uncertainty. The large uncertainty associated with these important parameters is directly attributable to assumptions regarding future states. In both cases the current guidance in Appendix C of 40 CFR 191 was implemented and was the source of the uncertainty. Background documents for 40 CFR 191, however, indicate that the assumptions that were used in developing the guidance in the appendix are not necessarily realistic. As an example, Ross (15) addresses the development of the EPA's criteria for intrusion by drilling into nuclear waste repositories. He points to flaws: first, the estimates are based on the rate of "forgetting" about the repository; and, second, that the assumption that drilling rates in salt will continue indefinitely at the high frequencies associated with the current oil-based economy is unlikely.

The EPA made assumptions in order to perform analyses prior to developing the 40 CFR 191, Final Rule, because analyses were required even while unknowables introduced great uncertainty. Thus, it is entirely appropriate for the EPA to establish assumptions for the treatment of human intrusion in performance assessments for potential repositories.

Undisturbed Performance

Assumptions must be made about future states of society to establish parameters for evaluating the impacts of doses to humans during undisturbed performance. Unknowable uncertainties about pathways through the accessible environment, population distributions, and the biosphere could be removed from the analyses by specifying that these future states can be assumed to be the same as those in existence on the date the implementing agency determines compliance.

Performance assessments to date predict no radionuclide releases to the accessible environment at the WIPP from undisturbed performance (6,7,8). However, considerations related to assumptions about future states of society are potentially of concern for undisturbed performance for other repositories.

In the Background Information Document for the 1985 Final Rule (13), the EPA stated:

> "...the Agency recognizes that it is pointless to try to make precise projections of the actual risks due to radionuclide releases from repositories. Population distributions, food chains, living habits, and technological capabilities will undoubtedly change in major ways over 10,000 years. Unlike geological processes, they can be realistically predicted only for relatively short times. Accordingly, very general models of environmental pathways were formulated as opposed to the detailed analytical techniques that would be appropriate for near-term environmental assessments of specific facilities. Population characteristics similar to those of today were assumed."

The WIPP LWA (5) in 1992 reinstated the Containment Requirements of 40 CFR 191 and mandated the repromulgation of the Individual Protection and Groundwater Protection Requirements. Prior to the Act, the EPA had suggested, in its Draft *Federal Register* notice of February 3, 1992 on repromulgating 40 CFR 191, the following:

> "Uncertainties involving things that are unknowable about the future can only be dealt with by making assumptions and recognizing that these may, or may not, correspond to a future reality. The [EPA] believes that speculation concerning certain factors should not be the focus of the compliance determination process. Therefore, it would be appropriate for assessments made under Part 191 to contain the assumption that many factors are essentially the same as today's. Factors which could be included in this category include demographic patterns, e.g., emergence of large populations where there are currently none, level of knowledge and technical capability, human physiology and nutritional needs, the state of medical knowledge, societal structure and behavior, and pathways through the accessible environment. The [EPA] would not find it appropriate to extend this to geologic, hydrologic, and climatic conditions, or total national or world populations."

The EPA deferred consideration of future states in 40 CFR 191 in favor of considering them in certification criteria for the WIPP (40 CFR 194). Guidance similar to the above (except for the issues related to population) would clarify the treatment of undisturbed futures that is needed for all repositories.

GUIDANCE ON PASSIVE INSTITUTIONAL CONTROLS

The preliminary performance assessments, and in particular, the expert panel that was convened to consider markers at the WIPP, provided information about specifics of passive institutional controls (PICs) that should be clarified. These areas are 1) the definition of "practicable," 2) specific criteria in 40 CFR 194, and 3) the use of expert judgment for the development and evaluation of passive institutional controls.

Guidance on the Definition of "Practicable"

In providing guidance on passive institutional controls, § 191.14 (Assurance Requirements) states:

> "To provide the confidence needed for long-term compliance with the requirements of 191.13, disposal of spent nuclear fuel or high-level or transuranic wastes shall be conducted in accordance with the following provisions, except that these provisions do not apply to facilities regulated by the Commission...:"
>
> "(c) Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls *practicable* [emphasis added] to indicate the dangers of the wastes and their location."

Guidance on what constitutes "practicable" is a legitimate concern. By communicating the dangers and location of the wastes, the passive institutional controls (PICs) are intended to ensure that future societies do not inadvertently intrude upon a repository. EPA's Guidance to 40 CFR 191 assumes that with knowledge, future potential intruders will cease their activity:

> "The Agency assumes that, as long as such passive institutional controls endure and are understood, they: 1) can be effective in deterring systematic or persistent exploitation of these disposal sites; and 2) can reduce the likelihood of inadvertent, intermittent human intrusion to a degree to be determined by the implementing agency."

and

> "Furthermore, the implementing agencies can assume that passive institutional controls or the intruders' own exploratory procedures are adequate for the intruders to soon detect, or be warned of the incompatibility of the area with their activities."

This assumption suggests that the controls are meant to deter unintentional human intrusion.

In response to existing EPA guidance, and at the DOE's request, Sandia National Laboratories (SNL) has taken steps to investigate appropriate criteria for markers to deter inadvertent human intrusion. The WIPP Marker Development expert judgment panel (Markers Panel) was convened. The Markers Panel was charged both with developing marker designs for long-term survival and communication and with estimating the efficacy of such marker designs in physically surviving and in maintaining their ability to communicate with potential future societies. Their recommendations were reported to SNL and the DOE and are published in a report by Trauth et al. (9). The recommendations from the Markers Panel suggest that markers capable of long-term survivability and communication could be quite expensive to implement.

Furthermore, the guidance for the Assurance Requirements requires actions to complement the Containment Requirements, yet the Containment Requirements themselves do not require the complete elimination of inadvertent human intrusion. Therefore, what actions are required to complement the Containment Requirements?

Clearly, the level of effort required is an important factor. There are a number of potential approaches to establishing the extent of PICs to implement and different levels of effort for each approach. It would be useful, not just for the WIPP, but for any repository program, to know what approach(es) the EPA deems acceptable, and at what level an approach should be pursued.

As an example, resources for designing, testing and implementing a single component (markers, records, etc.), or PICs as a whole, could be invested up to a specified dollar amount, a percentage of total project costs, or some other cost measure. A second approach might be to focus PIC efforts on protecting against a specified threat, as in focusing on the period of greatest risk of intrusion--before petroleum resources are depleted or before the U.S./world is no longer on a petroleum-based economy. A third possible approach might be to require resources be allocated to PICs until a certain benefit was achieved. The benefit might be reaching a specified level of risk of premature death from cancer, a reduction in the calculated risk of premature death from cancer (with and without PICs), or a specified movement of the complementary cumulative distribution function (CCDF) away from the EPA limits. A fourth possible approach is to combine the above two approaches into a cost/benefit analysis, with the EPA specifying the limiting cost/benefit ratio as well as the measure of benefit. A potential difficulty with the third and fourth approaches is that it could be costly to quantify the benefits and costs, particularly given the qualitative intent of the Assurance Requirements.

A related problem concerns the performance of a well-sited repository. For such a repository, that provides good isolation of radionuclides from the accessible environment, accruing additional benefits by implementing PICs would be more costly than for a poorly sited repository. The question, then, is how would the above approaches be implemented for a well-sited repository.

Finally, it would be helpful for the EPA to indicate what other PIC components (other than markers and records) would be considered appropriate or required for compliance with the Assurance Requirements.

Guidance on Criteria in 40 CFR 194 on Passive Institutional Controls

When guidance has been established regarding the term "practicable," it will also be important to establish the appropriate approach to be taken in the development of passive institutional controls. The efforts of the previously described Markers Panel (9) suggest an option for the development of criteria for PICs. This option will incorporate current developments, will reduce unwarranted expenditures, and yet will show sufficient progress in the implementation of controls that WIPP can be considered for a certification of compliance with § 191.14.

The Markers Panel was divided into two teams with the same charge in order to elicit a broader diversity of opinion. As the teams worked to develop a system of markers for the WIPP, they identified a number of fundamental principles that guided their work and that should guide future marker development efforts. These fundamental principles began with the moral imperative to mark the WIPP (in agreement with the mandated use of markers in § 191.14) and to be truthful in the messages rather than attempting to frighten or

mislead future socicties. The teams also identified the need for multiple levels of messages (corresponding to the complexity of the information) on multiple types of markers, the importance of linking the markers to off-site archives, and the necessity of using materials of little intrinsic value that would discourage recycling.

The two teams agreed and disagreed concerning different aspects of marker-system design and thus produced the desired diversity in potential designs. Both teams recommended the use of earthen berms, stone markers, small buried message markers, message chambers, and markers connected to outside archives in their designs. The disagreement between the teams centered on whether to attempt to use the principle of human archetypes in communicating through the marker system (communicating through the feeling evoked by the markers on a basic human level) or whether to develop a marker system that communicates purely through the construction and arrangement of the markers and the messages on the markers.

In providing their recommendations, the team members stated that some specific/detailed questions about markers and communication could only be answered through testing. The topics were 1) physical properties--durability of marker materials under current conditions at the WIPP, mechanism of attaching or inscribing messages, and the interaction of wind/sand/water with marker materials and configurations; 2) interpretation of graphic or pictorial messages that are independent of culture; and 3) interpretation of written messages that are independent of culture. The testing for (2) and (3) would probably involve a stepped process of developing messages that incorporates existing knowledge from communications theory and then tests the messages for comprehension with individuals who are not part of the dominant U.S. culture.

The findings from the Markers Panel suggest the possibility of implementing one type of PIC. One of the findings of the Markers Panel was that it is possible to construct markers that would last well into the period of regulatory concern. This is supported by the physical evidence of monuments that have survived for thousands of years. It is further supported by information from the field of materials science relating to material properties and interactions. Another finding is that there are many means available to achieve successful communication over long periods of time. This is supported by evidence of current human successes in interpreting ancient communications, as well as by current research into improving communications.

Clearly, developments in other disciplines integral to the development of a marker system have and will continue to improve the ability to design and construct markers to deter inadvertent human intrusion into a disposal system. It is only prudent to incorporate such developments into a final marker-system design, the implementation of which may require considerable resources. Such a final design probably will be decided upon and implemented after decisions have been made on the certification of compliance of the WIPP with 40 CFR 191. In addition, it would be imprudent to use resources on detailed designs before a decision has been made that the WIPP will in fact accept wastes for disposal. The question thus arises as to how to allow sufficient leeway in the development of PICs to incorporate research developments and the prevention of unwarranted expenditures, while still showing sufficient progress in their implementation for a certification of compliance of the WIPP with § 191.14.

An option for the EPA in establishing criteria for PICs is to require actions to be undertaken in a timely and reasoned fashion to indicate a serious effort to develop and implement appropriate PICs. Criteria to be promulgated at 40 CFR 194 should require the development and phased implementation of a non-prescriptive plan for each required PIC. The plan itself could address such topics as a) the disciplines pertinent to the specific type of control, b) the current state of knowledge in the pertinent disciplines, c) evaluation of available information to suggest initial options for the control, d) preliminary evaluation of options in terms of the definition of "practicable" from EPA (e.g., costs and benefits), e) the ongoing evaluation of research being conducted in the identified disciplines, f) appropriate specific research that the project should undertake, g) cut-off date for the consideration of new technologies and final evaluation of research, h) development of final design criteria, i) iterative design and evaluation phase, j) final "practicable" evaluation, k) implementation, l) how to address potentially contradictory new information, m) tentative schedule, and n) required documentation of the process.

Similar plans could be required for the development of active institutional controls and a monitoring program.

Guidance on the Use of Expert Judgment in the Development and Evaluation of Passive Institutional Controls

Existing guidance in 40 CFR 191 indicates that expert judgment is appropriate in developing passive institutional controls:

> "Determining compliance with § 191.13 will also involve predicting the likelihood of events and processes that may disturb the disposal system. In making these various predictions, it will be appropriate for the implementing agencies to make use of...prevalent expert judgment relevant to the numerical predictions. In fact, sole reliance on these numerical predictions to determine compliance may not be appropriate; the implementing agencies may choose to supplement such predictions with qualitative judgments as well. "

and

> "The Agency assumes that, as long as such passive institutional controls endure and are understood, they...(2) can reduce the likelihood of inadvertent, intermittent human intrusion to a degree to be determined by the implementing agency."

The development of PICs, with its requirement for the synthesis of information from separate disciplines, requires the use of expert judgment. If the definition of "practicable" includes requirements for estimating the future benefits (extent to which they deter inadvertent human intrusion) of PICs, then expert judgments are certainly required. As with any other area of science, it is an entirely appropriate and normal procedure for scientists to examine evidence and draw conclusions from it.

The WIPP Marker Development expert judgment panel (9) provided estimates of the efficacy of markers to deter inadvertent human intrusion that were based on the implementation of the marker system developed by each team as described. The estimates were further based on the assumption that the testing described above would be conducted and implemented into the final specific marker-system

design. A third assumption implicit in the deliberations was that this effort was an exercise to investigate what was possible without resource constraints. Further expert judgment would be necessary to investigate markers options within resource constraints. Cost limitations could be examined at a future date when the definition of "practicable" had been addressed. For example, the time and resources allotted were not sufficient to determine the exact depth and design for a foundation for a stone monument. The assumption was made that testing would be undertaken to determine what foundation would be appropriate for the soil/rock conditions as well as the impact of erosion on the stability of markers at the WIPP. Similarly, resources were not allotted to investigate which graphical messages would be most effective in communicating with individuals whose cultures and level of technological sophistication differ from those of the U.S. Again, estimates of communication efficacy assumed that the necessary research had been conducted and incorporated into marker designs.

The estimation of marker (or any other PIC) efficacy and the incorporation of that efficacy into the performance assessment calculations can indicate that, in fact, PICs do complement the Containment Requirements by deterring inadvertent human intrusion.

Guidance affirming that it is appropriate to use expert judgment in the development of PICs and in the calculation of the benefits would help to clarify the EPA's expectations.

GUIDANCE ON THE APPLICATION OF 40 CFR 141 MAXIMUM CONTAMINANT LEVELS TO 40 CFR 191.24

Because the definitions relating to groundwater changed in the 1993 version of 40 CFR 191, from "special source of ground water" to a less restrictive "underground source of drinking water" (USDW), and because the time limits were extended from 1,000 to 10,000 years (2), it is appropriate to request guidance from the EPA in two specific areas for the implementation of Subpart C: characterization of USDWs and the means by which compliance with groundwater requirements should be addressed.

The first area where guidance is requested is an effort to save taxpayer money and project time by not requiring the characterization of potential USDWs that would not contribute to a determination of compliance. Specifically, the EPA should clarify when a characterization of potential underground sources of drinking water is required, and when compliance could be determined without characterizing potential USDWs.

Guidance regarding these areas could be provided in a 3-step process:

1. If analyses undertaken for a showing of compliance with 40 CFR 191.13 and 191.15 provide a reasonable expectation that there will be no releases to the accessible environment for undisturbed performance for 10,000 years, then compliance with Subpart C can be assumed without identification and characterization of potential USDWs.
2. If analyses undertaken for a showing of compliance with 40 CFR 191.13 and 191.15 suggest that there may be releases to the accessible environment for undisturbed performance, and if the peak releases to the accessible environment at any point on its boundary at any time during the 10,000 year period of regulatory concern do not exceed the maximum contaminant levels (MCLs*)for radionuclides, then compliance with Subpart C can be assumed without identification and characterization of potential USDWs.
3. If analyses undertaken for a showing of compliance with 40 CFR 191.13 and 191.15 suggest that there may be releases to the accessible environment for undisturbed performance, and if the peak releases exceed the maximum contaminant level (MCL) for any radionuclide, the leading edge of the contaminant plume at the point where it exceeds the MCL will be tracked for the remainder of the 10,000 year period of regulatory concern, potential USDWs along that path will be characterized for possible identification as such, and modeled concentrations of radionuclides will be compared with the MCLs in any identified USDWs to ascertain compliance with Subpart C.

In the second area of proposed guidance, if a repository program were to be required to model concentrations of radionuclides for comparison with Subpart C, then the means by which they are to be compared should be addressed. Earlier guidance (currently contained in Appendix C of 40 CFR 191) stated:

> "Compliance with Sections 191.15 and 191.16 [Individual Protection Requirements and Groundwater Protection Requirements]. When the uncertainties in undisturbed performance of a disposal system are considered, the implementing agencies need not require that a very large percentage of the range of estimated radiation exposures or radionuclide concentrations fall below limits established in §§ 191.15 and 191.16, respectively. The Agency assumes that compliance can be determined based upon "best estimate" predictions (e.g., the mean or the median of the appropriate distribution, whichever is higher)."

Such guidance would reaffirm that a probability distribution of radionuclide concentrations was the appropriate means of representation of this information. This is an appropriate request since the EPA has also indicated a preference in the guidance to 40 CFR 191 for the display of information for compliance with § 191.13 in the form of a CCDF.

Explicit guidance would also provide the means by which the probability distribution could be compared with the MCLs by specifying which realization within the probability distribution ("the mean or the median of the appropriate distribution, whichever is higher") to use.

CONCLUSIONS

The guidance proposed here concerns three areas: future states, passive institutional controls, and groundwater requirements. Preliminary assessments of the performance of the WIPP repository, including expert judgment panels on future societies and passive institutional controls, indicate that difficulties may arise in these three areas if guidance is

* The maximum contaminant levels (MCLs) are either limitations in terms of either radionuclide concentrations or radionuclide concentrations that will produce certain doses for water delivered to any user of a public water system (3). For the implementation of subpart C (§ 191.24), the limitations on water delivered to a user of a public water system after treatment are applied to the USDW without treatment.

ambiguous or nonexistent. Thoughtful consideration by the EPA of the arguments presented here would be useful not only to the WIPP Project, but also to future repository programs.

ACKNOWLEDGEMENTS

The authors would like to thank Marilyn M. Gruebel (Tech Reps, Inc.) and Peter N. Swift (SNL) for their review of the paper and their helpful insights. The authors would also like to thank Janet Chapman (Tech Reps, Inc.) for her editorial support.

This work was performed at Sandia National Laboratories (and is documented as SAND93-2441C), which is supported by the U.S. Department of Energy under contract DE-AC04-94AL85000.

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