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

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ABSTRACT

Preliminary performance assessments (PAs) have been conducted for the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico. These PAs assess the ability of the WIPP, a proposed disposal facility for defense-generated nuclear waste, to comply with EPA's requirements at 40 CFR 191. The experience in conducting PAs has provided insights into guidance that would facilitate the conduct of studies and analyses required by the regulation. Guidance topics and suggested directions are discussed for possible inclusion in EPA rulemaking for WIPP-specific compliance criteria to be found at 40 CFR 194.

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 and mixed TRU waste at the WIPP, 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 (PA) 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. Within Subpart B, PA analyses attempt to indicate expected performance of a disposal system for 10,000 years and compare them to probabilistic radionuclide release limits found at § 191.13. The radionuclide doses that individuals may receive from a disposal system are limited for 10,000 years in § 191.15. The Assurance Requirements, found at § 191.14, indicate supplementary actions to be taken to account for the uncertainties in the conduct of analyses of a disposal system over the regulatory period (10,000 years). Subpart C incorporates the requirements of National Primary Drinking Water Regulations (40 CFR 141.15 and 141.16) (3) to protect underground sources of drinking water (USDW) that might be impacted by a disposal system for 10,000 years.

NEED FOR ADDITIONAL GUIDANCE

The repromulgation of 40 CFR 191 addressed problems that arose from the 1987 court decision. Both the repromulgated rule and that from the 1985 Final Rule require further guidance from EPA for appropriate implementation. The EPA is developing compliance criteria for the WIPP to be codified at 40 CFR 194. Now is the time for the experience from years of performing preliminary PAs

and from the effort to develop permanent, passive markers to be used to indicate to the EPA what guidance would be most helpful to a repository program. While it may not be appropriate to place guidance for the general rule in WIPP-specific criteria, guidance is necessary no matter in what form it appears. The following are major areas where additional guidance to the general rule (applicable to all repositories except those specifically exempted) appears necessary.

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 all nuclear waste repositories.

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. Future state assumptions based on current conditions will avoid the inadvertent specification of future-state-related siting criteria. Such assumptions implemented on a site-specific 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 (now Appendix C) to 40 CFR 191 focused on the affects of human intrusion on geologic waste repositories. 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, EPA has focused attention on future states and human intrusion assumptions 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 (4). EPA emphasis, 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 has become the 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 could be done 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 active institutional contols (AICs) and passive institutional controls (PICs). This would eliminate these uncertainties from the analyses.

The EPA has long recognized the difficulty and inappropriateness of trying to precisely project the actual risks of releases because of likely changes in population distributions, food chains, living habits, and technological capabilities (5,6,7,1). The EPA has also recognized that the effects of intrusion of a repository by humans is an important source of uncertainties in performance assessments (1).

According to the 1992 performance assessment calculations (8), 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 is implemented and is the source of the uncertainty. Background documents, however, indicate that the assumptions that were used in developing the guidance in the appendix are not necessarily realistic. As an example, Ross (9) 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, the assumption that drilling rates in salt will continue indefinitely at the high frequencies associated with the current oil-based economy is unlikely.

Undisturbed Performance

Assumptions must be made about future states of society to establish parameters for evaluating the impacts of releases from a repository during undisturbed performance. Unknowable uncertainties in 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 accessibel environment at the WIPP from undisturbed performance. However, considerations related to assumptions about future states of society are potentially of concern for other repositories.

The WIPP Land Withdrawal Act (10) reinstated the Containment Requirements of 40 CFR 191 and mandated the promulgation of the Individual Protection and Groundwater Protection Requirements. Prior to the Act, the EPA had suggested, in working draft 4 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 is needed for all repositories.

GUIDANCE ON THE DEFINITION OF "PRACTICABLE" FOR PASSIVE INSTITUTIONAL CONTROLS

Section 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."

By communicating the dangers and location of the wastes, the 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 suggests that PICs are meant to prevent unintentional human intrusion.

In response to existing EPA guidance, and at DOE's request, SNL has taken steps to investigate what are appropriate criteria for markers to deter inadvertent human intrusion. The WIPP Marker Development expert judgment panel was convened. The Markers Panel was charged with developing marker designs whose characteristics were such that they suggested long-term survival and communication. They were also charged 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 DOE and are published in a report by Trauth et al. (11). The recommendations from the Markers Panel suggest that markers capable of long-term survivability and communication could be quite expensive to implement.

At the same time that § 191.14 requires actions to complement § 191.13 (Containment Requirements), the Containment Requirements themselves do not require the complete elimination of inadvertent human intrusion, but allow for some radioactive releases into the accessible environment. Dual requirements indicate a need to determine what actions will fulfill the requirement to complement § 191.13 without necessarily guaranteeing the elimination of potential intrusion.

Because of the great expense that is potentially associated with the interpretation of the word "practicable" over the 10,000 year period of regulatory concern, it is a legitimate request that EPA provide further guidance. 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) EPA deems acceptable, and at what level an approach should be pursued.

As an example, resources for design, testing and implementation of 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 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, or a specified movement of the CCDF away from the EPA limits. A third possible approach is to combine the above two approaches into a cost/benefit analysis, with EPA specifying the limiting cost/benefit ratio as well as the measure of benefit. A fourth 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.

There are several related areas where guidance would be useful. The first is what other PIC components (other than markers and records) would be considered appropriate or required. A second question is whether specified benefit measures are for a particular component or for PICs as a whole. A third problem area is the minimum level of effort required if a repository, without PICs, achieves the benefits specified or surpasses the limiting cost/benefit ratio.

GUIDANCE ON 40 CFR 194 CRITERIA FOR PASSIVE INSTITUTIONAL CONTROLS

The efforts of the previously described Markers Panel (11) suggest an option for the development of criteria for PICs.

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 societies. 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 be difficult to recycle.

The two teams agreed and disagreed in different aspects of marker-system design and thus produced the desired diversity in potential designs. Both teams recommended the use of earthen

berm, 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 of 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 incorporate existing knowledge from communications theory and then testing the messages for comprehension with individuals who are not part of the dominant U.S. culture.

The findings from the Markers Panel suggest the possibilities 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 support 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 will not be decided upon and implemented until decisions have already 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 a proposed site 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. The first step in this option requires the EPA to provide guidance related to the use of the term "practicable." This guidance will indicate to the DOE what areas must be investigated for PICs and the level of effort and expense that is appropriate for their implementation. Criteria to be promulgated at 40 CFR 194 should require the development and phased implementation of a plan for each required PIC. The plan itself could address such topics as (1) the disciplines pertinent to the specific type of control, (2) the current state of knowledge in the pertinent disciplines, (3) evaluation of available information to suggest initial options for the control, (4) preliminary evaluation of options in terms of the definition of "practicable" from EPA (i.e., costs and benefits), (5) the ongoing evaluation of research being conducted in the identified disciplines, (6) appropriate specific research that the project should undertake, (7) cut-off date for the consideration of new technologies and final evaluation of research, (8) development of final design criteria, (9) iterative design and evaluation phase, (10) final "practicable" evaluation, (11) implementation, (12) how to address potentially contradictory new information, (13) tentative schedule, and (14) 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 OF PASSIVE INSTITUTIONAL CONTROLS AND THEIR USE IN PAS

Efforts to develop PICs highlight the need for guidance on the appropriate role of expert judgment in such endeavors. Such guidance would be expected to reaffirm and clarify the existing Guidance to 40 CFR 191:

> "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 Markers Panel (11) 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. Cost limitations could be included at a future date what 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 wind/sand/water conditions 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 PA 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 clarify what EPA expects and would find acceptable.

GUIDANCE ON THE APPLICATION OF 40 CFR 141 MAXIMUM CONTAMINANT LEVELS TO 40 CFR 191.15

With the changing definitions relating to groundwater--from "special source of ground water" to "underground source of drinking water," (USDW) and the extension of the time limits from 1,000 to 10,000 years (2), it is appropriate to request guidance from EPA in two specific areas for the implementation of Subpart C for the general regulations.

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, EPA is asked to clarify when a characterization of potential underground source of drinking water is required, and when compliance could be determined without characterizing potential USDWs.

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

As a start, guidance could be provided in a three-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, 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 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.

If a repository program were to be in the position of having to model concentrations of radionuclides for comparison with Subpart C, the second area for requested guidance would arise. This guidance could be provided by reaffirming the guidance EPA previously provided for 40 CFR 191 for how compliance with the Groundwater Requirements (previously at § 191.16) should be addressed:

> "Compliance with Sections 191.15 and 191.16. 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 complementary cumulative distribution function (CCDF).

Such 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.

With the changes to the manner in which groundwater is to be protected (direct incorporation of the MCLs) and to the length of time for consideration (from 1,000 to 10,000 years), as well as the movement of groundwater issues from § 191.16 within Subpart B to a new Subpart C, EPA should reaffirm the above guidance explicitly.

CONCLUSIONS

The guidance proposed here represents some of the concerns of a repository program in implementing the requirements of 40 CFR 191. The thoughtful consideration by EPA of the arguments presented here would be useful to the WIPP and to future affected repository programs.

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