Obligation to Future Generations: The Interplay of Science and Policy

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ABSTRACT[1]

This paper considers how the effort to manage radioactive waste in the United States addresses questions of obligation to future generations. After some introductory comments to set the stage, it starts with a brief discussion of the issues that arise during the time a repository is being developed and operated: financing, monitoring, and communication across time. This discussion concludes that the ground rules established appear appropriate in principle but that the devil may be in the details of their implementation. The paper then considers in greater depth the issues associated with protecting the health of future generations once a repository is closed: inadvertent human intrusion and the time over which the safety standard must be satisfied. The paper concludes that key social and ethical questions have not been addressed directly but have been resolved through the use of technical arguments. Such an approach needs to be adopted deliberately and not thoughtlessly or by default.

Keywords: radioactive waste management, intergenerational equity, repository monitoring, human intrusion, compliance period.

INTRODUCTION

The German philosopher, Hans Jonas, poses the central ethical issue of our technological age as he observes that the days have passed when:

> The good and evil about which action had to care lay close to the act, either in the praxis itself or in its immediate reach, and were not a matter for remote planning…Proper conduct had its immediate criteria and almost immediate consummation. The long run consequences were left to chance, fate, or providence. Ethics, accordingly, was of the here and now, of occasions as they arise between men, of the recurrent, typical situations of private and public life.

Instead, suggests Jonas,

> [This] sphere is overshadowed by a growing realm of collective action where doer, deed, and effect are no longer the same as they were in the proximate sphere, and which, by the enormity of technology's powers, forces about ethics a new dimension of responsibility never dreamt of before. [1]

Advocating a new categorical imperative—"In your present choices, include the future wholeness of Man among the objects of your will"—Jonas recapitulates a theme that underlay the intent of those managing radioactive wastes from the time they were first created, more than a half century ago.

THE CHALLENGE OF RADIOACTIVE WASTE MANAGEMENT

High-level radioactive waste (HLW) and spent nuclear fuel (SNF) are created in the course of powering nuclear submarines, producing plutonium for nuclear weapons, and most extensively, generating electricity at nuclear power plants. Although those materials decay over time, they remain toxic and pose risks to man and his environment for many thousands of years. Consequently, from the moment of their formation, they have been actively managed to minimize the harm they might cause. For the past six decades, HLW and SNF have been stored, typically at the locations where they were created. However, many countries, including the United States, have adopted policies and programs to isolate and contain those wastes for very long periods by disposing them in deep underground structures called repositories. [2,3]

Initially, the task of developing a repository was conceived as a straightforward application of science and engineering. The view of those in charge, only partly facetiously, was: all we need to do is dig a hole, dump the stuff, and bury it. In retrospect, the technical task proved far more difficult than first anticipated. Furthermore, over the years, social and institutional aspects of the problem became more prominent. For example, the integrity of the process for selecting a repository site generally came under close scrutiny. Issues of trust in the institutions assigned waste management responsibilities often had to be addressed. In no small part because of the complexity of the task, no repository has yet been developed for HLW and SNF.

But remarkably, for more than half a century, in the face of frustrations and delays, an almost universal commitment has been made to finding a permanent solution to the problem of managing HLW and SNF. This commitment has been maintained to a large degree because radioactive waste management has always been suffused with a concern—sometimes implicit, sometimes generalized, sometimes marginal, but a concern nonetheless—about the well being of generations far removed from the ones that created the waste.

[1]The views in this paper do not represent the views of the Nuclear Waste Technical Review Board, an independent agency of the U.S. Government charged with evaluating the scientific and technical validity of the Department of Energy's high-level radioactive waste management program.

DEVELOPMENT AND OPERATION OF A REPOSITORY

Provisions for Protecting the Health of Future Generations

When they established the ground rules for developing and operating a repository in the United States, the Congress and two regulatory agencies, the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC), recognized the special requirements associated with radioactive waste disposal.[2] First, in passing the Nuclear Waste Policy Act, Congress ratified the principle that the generation(s) that created the HLW and SNF would bear the costs of disposing of those materials in a manner that imposes no undue risks on future generations. Consumers of nuclear-generated electricity pay a surcharge for disposing of commercial SNF; contemporaneous appropriations cover the costs of disposing of defense-generated waste. The Department of Energy (DOE), which has the responsibility for developing a repository, periodically evaluates whether the anticipated revenues will be sufficient.

Second, both the EPA and the NRC require that the DOE use a quantitative performance assessment (PA) to demonstrate that its proposed repository will satisfy an individual protection standard. This projected performance, based on complex computer models, cannot be *proven* in the "ordinary sense of the word." Thus, the NRC also requires that the DOE develop a performance confirmation program that challenges key assumptions and models used in the PA. Under the performance confirmation program, critical variables and parameters will be monitored during the time the repository is open. Should monitoring reveal that fundamental problems have arisen, the NRC mandates that a repository must be designed so that the HLW and SNF can be retrieved within 50 years after waste emplacement operations are initiated.

Third, the NRC directs the DOE to maintain complete records of the receipt, handling, and disposition of radioactive waste in a repository. Those records have to contain sufficient information to provide a complete history of the movement of the HLW and SNF from the shipper through all phases of storage and disposal. Specifically, the DOE has to retain these records "in a manner that ensures their usability for future generations."

Implementation Questions

The ground rules established by Congress and by the EPA and the NRC not only permit but actually encourage an incremental, trial-and-error, learning approach to repository development. Organization theorists as well as subject-matter experts have long accepted that this approach is appropriate in principle, given the conditions present during the time a repository is being developed and operated. [4,5]

Yet implementing such an approach may not be as easy as one might hope. To begin with, the approach depends on the availability of clear "error" signals, i.e., information suggesting that expected outcomes have not, in fact, been realized. Although such unambiguous signals might emerge, I suspect that more frequently the information obtained tends to be opaque and subject to varying interpretations. Two examples drawn from the DOE's experience characterizing the proposed repository site at Yucca Mountain in Nevada illustrate this point. Both examples involve the movement of water, which is the most important mechanism for potentially transporting waste from the repository to the accessible environment.

The first example began to unfold in 1996, when investigators from Los Alamos National Laboratory discovered that chlorine-36 was present at a depth of 300 meters below the crest and about 200 meters above the water table. Although this isotope occurs naturally, it was found at such high concentrations that investigators concluded that it originated in above-ground nuclear weapons tests. This conclusion implied that water carrying the isotope traveled 300 meters in approximately 50 years, a rate substantially faster than previously projected. Several years later, investigators from Lawrence Livermore National Laboratory replicated the experiment and found no trace of elevated chlorine-36. Even after the scientists standardized their experimental protocols, their findings remained contradictory. So nearly a decade later, it is still unclear how fast water is moving at Yucca Mountain.

The second example began to unfold in 1999, when the DOE closed off a portion of an exploratory tunnel beneath Yucca Mountain to measure how much water seeped into the drift. Subsequently, drops of water were observed on equipment and on the tunnel floor. The DOE's models, however, predicted that very little water, and perhaps none at all, would seep into the tunnels holding HLW and SNF in the proposed repository. To explain the observed fluid, the DOE hypothesized that water vapor found in the air underground condensed and was deposited as a liquid. Efforts to confirm or reject that hypothesis have been inconclusive. So a half a dozen years later, it is still unclear how much water will seep into the area where waste might be emplaced at Yucca Mountain.

Another obstacle to implementing an incremental, trial-and-error approach successfully is the demands that the strategy places on organizations. A study undertaken by a panel convened by the National Academy of Sciences (NAS) specified some of the conditions needed to foster "learning organizations." [6] Among others, these conditions include:

- A commitment to acquiring and incorporating new knowledge
- A willingness to reevaluate earlier decisions
- Maintaining the option to reverse course
- Well-documented and open decision-making
- Integrity—saying what you will do and doing what you say
- Seeking, acknowledging, and acting on new information provided by individuals and groups outside the organization
- Perceived trustworthiness
- Assurance that agreements will be kept and continuity maintained for many generations

There are few, if any, historical examples of organizations fulfilling all these conditions for long periods. Not surprisingly then, there are few, if any, historical examples of where an organization has successfully implemented over the long haul the kind of incremental, trial-and-error approach that appears to be so attractive. [7] Perhaps more to the point, the TBYMS panel noted that the DOE would have to change its mode of operation in fundamental ways to make its repository development efforts more adaptive.[3]

[2] The EPA sets the standards for disposing of radioactive waste, and the NRC develops regulations that implement those standards in the context of a process to license repositories.

[3] See the Panel's discussion in Appendix F.

ENSURING SAFETY AFTER THE REPOSITORY IS CLOSED

Above all, this generation's obligation to future generations centers on the duty of the former to protect the health of the latter. To understand fully the nature of this duty we are forced to explore closely as well the character of the standards and regulations that have been promulgated for ensuring safety after the repository is closed. It demands also that we explore how those standards and regulations are satisfied. This paper, however, only addresses the first of the two tasks.

Inadvertent Human Intrusion

Over the years, those managing HLW and SNF have confronted the following scenario. At some point while the waste still remains hazardous, existing social forms may collapse. All institutional memory about the location and contents of a repository may be lost. All mechanisms for communicating this information, such as signs and markers, may fail to achieve their purpose. Under those circumstances, it becomes conceivable that some individual or group could inadvertently breech the barriers isolating and containing the waste. Unexpected pathways could then open, facilitating the movement of the waste into the environment. What can this generation do to forestall this possibility?

The EPA's first standard: One approach taken in 1985 was to encourage the siting of a repository in locations that do not contain minerals or water that were commercially valuable. Employing that siting criteria could reduce the likelihood of breeching a repository.

Another approach was to treat human intrusion as one type of "disruptive event," whose impacts had to be evaluated. The EPA defined the likelihood of intrusion and bounded the amount of material that might be released. The expected level of release as a result of inadvertent human intrusion was then added to the amount of material an undisturbed repository was expected to release. The total had to meet a rather complicated standard.

The EPA's second standard: A key part of the 1985 standard was overturned by a federal court in 1987, forcing the entire regulatory structure for disposing of HLW and SNF into a legal limbo. In 1992, while the EPA was reconsidering what it should do in response, Congress passed Section 801 of the Energy Policy Act (EnPA). That section instructed the EPA to contract with the NAS to develop the technical bases for a new environmental standard, specific to the proposed Yucca Mountain repository. Congress also told the EPA to promulgate that new standard "based on and consistent with" the findings and recommendations of the NAS-sponsored study.

The panel appointed by the NAS to conduct the study published its analysis, *Technical Bases for Yucca Mountain Standards* (TBYMS), in 1995. [8] The panel directly addressed two questions posed to it by Congress. It found it was unreasonable to assume that any system of post-closure oversight could be developed that would function for many thousands of years. In addition, the panel concluded that there was no scientific basis for predicting either the nature or the frequency of occurrence of human intrusion. Hence it recommended that only the consequences of an intrusion be calculated to assess the resilience of a repository to such an event. Going further, the panel proposed a scenario that might "test" the repository.

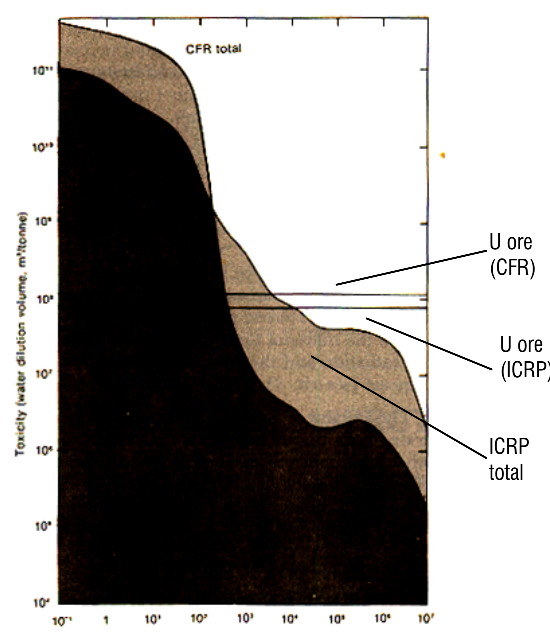
In 2001, the EPA completed its review of the TBYMS study and published its new Yucca Mountain standard. It decided to use a stylized scenario—slightly modified from the one the NAS-appointed panel proposed—to evaluate only the consequences of inadvertent human intrusion. Under that scenario, the consequences of human intrusion provide a test for the repository only if two conditions held:

- Within 10,000 years after a repository is closed, an "intruder" penetrates a waste package, continues drilling to an underlying aquifer, but is unaware that a breech has occurred;
- The dose due to the breech is received within 10,000 years after a repository is closed.

Compliance Period

In a draft report on the safety requirements for a repository, the International Atomic Energy Agency set forth as a fundamental principle: "Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are accepted today." What is left unanswered is how far into the future should that principle be applied. Put differently, what should be the compliance period? [9,10]

The early years: In the late 1960s and the early 1970s, when the United States first began to think about standards for disposing of radioactive waste, it was presumed that the material would be HLW, the solidified product of spent fuel reprocessing. Arguing that it was not the responsibility of nuclear-generated electricity to "purify" the earth, many promoted the position that a repository need not sequester waste beyond the time when it became less hazardous than the uranium ore from which it was derived. A rough measure of hazard was constructed, the water dilution volume—the amount of water it would take to dilute the waste to acceptable drinking standards. Drawing figures such as the one reproduced below, those advocates compared the hazard associated with the ore with the hazard associated with the waste as it decayed over time. Depending on what regulatory assumptions are used, the hazards appear comparable sometime no later than 10,000 years after the fuel was discharged from the reactor.



Source: [11]

The EPA's first standard: After working for more than five years, the EPA in 1982 proposed an individual protection standard that included a compliance period of 10,000 years. In its proposal, the agency premised its choice on the following lines of logic:

- Choosing 10,000 years for assessment encourages selection of sites where the geochemical properties of the rock formations can significantly reduce releases of radioactivity through groundwater.
- Major geologic changes, such as development of a faulting system or a volcanic region take much longer than 10,000 years. Thus, the likelihood and characteristics of geologic events which might disrupt the disposal system are reasonably predicted over this period.

The EPA went on to observe:

> There is one particular factor which has reinforced our decision about the reasonableness of the risks permitted under our proposed standards. This is our evaluation of the risks associated with undisturbed uranium ore bodies…Leaving the ore unmined appears to represent at least as great a risk to future generations as disposal of the wastes covered by these standards. We are not sure that this analysis provides an adequate means of resolving the question of intergenerational risk. It has, however, helped to influence our decision of what is an acceptable level of residual risk, given our current scientific, technological, and fiscal capabilities. [12]

These three lines of logic represent respectively a natural barriers rationale, a limited uncertainty rationale, and a comparative hazards rationale.

Nearly three years later, the EPA finalized its waste disposal standard. In explaining its choice of compliance period, the agency replaced the limited uncertainty rationale with a general one even as it effectively abandoned the natural barriers and the comparative hazards rationales. In particular, the EPA explained that not only would major geologic changes be more predictable if the compliance period did not exceed 10,000 years, but that *all* aspects of the calculations would be more certain. The agency further explained that a 10,000-year compliance period made sense because of an extrapolation rationale: "A disposal system capable of meeting requirements for 10,000 years would continue to protect people and the environment well beyond 10,000 years." [13]

The EPA's second standard: The TBYMS panel also offered a recommendation for dealing with the compliance period: within the limits imposed by the long-term stability of the geologic environment, which is on the order of 1,000,000 years, "compliance with the standard should be measured at the time of peak dose, whenever it occurs."[4] (See also [10]). The time of peak dose, of course, is highly dependent on the design of the entire disposal system as well as the assumptions and models used in the PA. But, for the proposed repository at Yucca Mountain, peak dose likely occurs sometime between 200,000 and 500,000 years into the future.

In making its recommendation, the TBYMS panel did not explicitly reject the EPA's general uncertainty rationale. Rather its argument was more subtle. Some sources of uncertainty, like those arising from spatial interpolation of site characteristics will be present at all times. And although others may increase, still others, like those associated with the engineered system, may decrease. What counts, said the panel, is the amount of confidence one has in the PA. The level of that confidence at 1,000,000 years was likely to be comparable to the level at 10,000 years. In effect then, the TBYMS panel argued, since a PA can be carried out in a meaningful way using a peak-dose compliance period, "there is no scientific basis for limiting the time period of the [individual protection] standard to 10,000 years or any other value."

In 1999, after evaluating and wrestling with the TBYMS report, the EPA solicited comments from the public on two alternative compliance periods: time of peak dose and 10,000 years. [14] In its analysis of the first alternative, the EPA explicitly rejected the TBYMS panel's conclusion that a PA carried out to the time of peak dose could be technically meaningful. In the regulators' view, "setting a strict numerical standard at a level of risk acceptable today for the period of geologic stability would tend to ignore" the large and cumulative uncertainties associated with such a PA.

The EPA supported its preference for the 10,000-year alternative by evoking several lines of logic, which it claimed were important to weighing technical and policy considerations—a weighing that the TBYMS panel declined to perform.[5] First, it advanced a consistency rationale. The EPA observed that other regulations it had adopted, notably those governing land disposal of hazardous wastes and the disposal of transuranic-contamined radioactive wastes in a deep geologic repository, contain a 10,000-year compliance period. Second, it put forward once again its general uncertainty rationale. This time, the EPA specified two sources of uncertainty that it believed most complicated the task of projecting repository performance to the time of peak dose: the natural changes in climate and the range of possible biosphere conditions and human behavior. Third, it asserted a universality rationale, somewhat dubiously noting that "many international geologic disposal programs" use a 10,000-year compliance period. Fourth, the regulators offered a management rationale.

> Focusing upon a 10,000-year compliance period forces more emphasis upon those features over which man can exert some control, such as repository design and engineered barriers…By focusing upon an analysis of the features that man can influence or dictate at the site, it may be possible to influence the timing and magnitude of the peak dose, even over times longer than 10,000 years.

Twenty-two months later, the EPA finalized its environmental standard for disposing of HLW and SNF at Yucca Mountain. [15] After reviewing the period of compliance issue, the agency maintained:

> *Despite the NAS's recommendation,* we conclude that there is still considerable uncertainty as to whether current modeling capability allows development of computer models that will provide sufficiently meaningful and reliable projections over a time frame of up to tens-of-thousands to hundreds-of-thousands of years. *[emphasis added]*

The regulators then reiterated, almost verbatim, the consistency, general uncertainty, universality, and management rationales articulated in the earlier notice of proposed rulemaking. The EPA finally concluded, "We believe the unprecedented nature of a compliance period beyond 10,000 years was very persuasive and related strongly to developing a meaningful standard that is reasonable to implement."

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[4] If one plots the expected value of the projected dose over time, then the time of peak dose is when that curve reaches its maximum value.

[5] The distinction between "technical" and "policy" considerations is, of course, often blurred.

The Aftermath: By 1985, several years after Yucca Mountain had been identified as a potential site, the State of Nevada had decided to oppose its development as a repository. Since then, the State has persistently raised technical and political objections to the effort. Beginning in 2000, the State filed a large number of lawsuits challenging actions with respect to the proposed repository. Among other things, it maintained that, in choosing the 10,000-year compliance period, the EPA violated Section 801 of the EnPA. Those cases were consolidated and were argued in early 2004 before the U.S. Court of Appeals for the District of Columbia Circuit. In July 2004, the Court issued its opinion. [16]

To evaluate the State's claim, the Court used the so-called *Chevron* test, a 20-year old doctrine developed by the Supreme Court as a means for determining whether an agency's action is consistent with congressional intent. *Chevron* contains two steps. In the first, the court asks whether the language of the statute is unambiguous. If it is, then it is a simple matter to determine whether the agency acted properly. If the language is ambiguous or silent, then the second step of *Chevron* kicks in: Is the agency's interpretation of its mandate a "permissible construction"? If so, it must be deferred to by reviewing courts.

In this case, the Court concluded under *Chevron*, Step One, that nothing in Section 801 specifies precisely how EPA must use the TBYMS study. Moving then to *Chevron*, Step Two, it determined that, notwithstanding the ambiguity, the EPA's construction was not permissible. The Court held that "the EPA unabashedly rejected the [TBYMS] panel's findings and then went on to promulgate a dramatically different standard, one that the panel had expressly rejected." In colorful language, the Court suggested that the EPA operated in a "Bizarro World" straight out of Superman comics. In that realm, "'based upon' means 'in disregard of' and 'consistent with' means 'inconsistent with'." The Court also addressed the EPA's argument that policy considerations could lead it to a different compliance period than the one the TBYMS panel recommended. But this position also did not pass muster. The EPA's stance, in the Court's view, was tantamount to saying that "compliance assessment [should] be conducted for the period that lacks a scientific basis but that best meets EPA's policy needs."

The Court vacated the portion of the EPA standard dealing with the compliance period. Because the EnPA requires that the NRC's licensing rule be consistent with the EPA standard, it also vacated the analogous portion of the NRC's regulations for licensing a Yucca Mountain repository.[6] As of the time this paper was completed, the EPA had not promulgated a new standard to comply with the Court's decision. Consequently, the director of the Yucca Mountain program suggested that the schedule for the DOE submitting an application to the NRC for permission to construct a repository would slip by two years. It remains to be seen whether the Court's decision will threaten the project's life.

[6]It is interesting to note that another Court of Appeals approved the 10,000-year period of compliance in the case of the repository for long-lived transuranic-contaminated radioactive waste, the Waste Isolation Pilot Plant (WIPP). What distinguishes the two cases is that the EnPA contained a specific requirement that the EPA develop a standard based on and consistent with recommendations from the NAS. Had not the DOE and the NRC pushed Congress to pass the EnPA to fix a "problem" created by the EPA's first standard, the gaseous radioactive C-14 releases from SNF to the atmosphere, the government would likely not be in the position it is today.

The Technical Basis for Selecting a Compliance Period

Over the last quarter century, the EPA has advanced a variety of reasons for why 10,000 years is the proper cut-off point to evaluate whether a repository complies with an environmental standard. Five of those explanations were premised on explicit technical arguments: the natural barriers rationale, the limited uncertainty rationale, the comparative hazards rationale, the extrapolation rationale, and the general uncertainty rationale.

The EPA has, for all practical purposes, abandoned the first four technical explanations, leaving only the general uncertainty rationale. Upon how firm a technical foundation does it rest? Certainly the recommendation of the TBYMS panel has met with more than a little resistance on this score.[7] Yet the fact remains that no one—not the EPA, the NRC, or the DOE—has carried out a systematic technical assessment that might be relied upon to resolve this issue. To be fair, conducting such an assessment is no trivial matter epistemologically, conceptually, methodologically, or empirically. But, in the final analysis, there are only conflicting professional *judgments and beliefs* held by experts of comparable note.[8]

TRANSFORMING SOFT QUESTIONS INTO HARD ANSWERS

Deciding how to discharge our obligation to future generations requires that an inextricable combination of technical, social, institutional, and profoundly ethical questions be addressed. Yet the foregoing discussion strongly suggests that soft, institutional and ethical, questions are never really debated, but instead they are just transformed into hard technical answers.

For example, we have some understanding of the conditions that either facilitate or retard organizational learning. That understanding, however, does not appear to be factored into thinking about performance confirmation. All that is required is an experimental plan. It is as if we simply presume that Alvin Weinberg's "nuclear priesthood" will be around to flawlessly detect problems and remediate them.

How the EPA dealt with the question of inadvertent human intrusion into a repository also illustrates this transformation. In theory, a PA could be carried out to determine whether intrusion would unacceptably compromise repository performance. To do so, a variety of scenarios would have to be specified along with their likelihood. The expected impact of all the scenarios on the isolation and containment of HLW and SNF would then be evaluated. Such an exercise, however, would require careful thinking about how future societies might behave. Instead, the EPA mandated that just one scenario be used to test a repository's response to intrusion.

[7]For example, my organization, the Nuclear Waste Technical Review Board, commented on the TBYMS report in a letter to the EPA. "[P]redictions of repository performance over such long time periods involve considerations other than geologic stability, such as climate change and the performance of engineered barriers. The Board expects that the uncertainties in projected human health risks will increase the farther those projections are extended into the future."

[8]The DOE recently presented state-of-the art age dating of opal mineral deposits that argued for stability of long-term seepage rates, independent of climate change. If the DOE is correct, climate change may not prove to be as great a contributor to uncertainty in performance as the EPA asserted because seepage rate is a major factor affecting repository performance.

But perhaps the most striking instance of this transformation involves the choice of compliance period. Embedded in this choice is a fundamental ethical principle that is seemingly widely accepted: do not export into the future risks that you are not prepared to bear in the present. Yet, for all practical purposes, the EPA's selection of a compliance period has never relied on its understanding of what the principle might demand. Rather the EPA's choice of 10,000 years has always been primarily based on technical rationales, none of which, more than incidentally, can be regarded as truly settled matters.

I suspect that these transformations resulted from at least three influences that acted both individually and through their interactions. First, the national government conferred upon the scientific and engineering communities an authoritative role in establishing the primary boundaries within which obligation to the future had to be defined. By interpreting the EnPA as it did, the Court of Appeals concluded that Congress wanted the technical judgments of an expert panel to constrain the EPA's discretion to balance "technical" and "policy" considerations. Although the Court noted that "had EPA begun with the recommendation to base the compliance period on peak dosage and then made adjustments to accommodate policy considerations not considered by the [TBYMS panel], this might be a very different case," it was quite clear that the regulators would be sanctioned if they stepped too far outside the area marked by the panel.

Second, the EPA standard has to be applied by the NRC in the context of a trial-like licensing proceeding, which is likely to be highly contentious. For this reason, the EPA asserted time and again that any rule it might promulgate had to be "implementable." Translated this means that the standard had to lay out clear guideposts for how the performance of a repository would be judged. Yet many, if not most, institutional and ethical questions are messy, and they may not have unambiguous or definitive answers. Hence their introduction into a licensing proceeding would open the door to speculative arguments that would be difficult and, perhaps more importantly, time-consuming to resolve.

Third, perceptions of long-term risk also helped to transform soft questions into hard answers. Based more on intuition than on rigorous analysis, many individuals inside the waste management community believe that the risk posed in the very far future by a well-sited and well-designed repository is not substantial, even in comparison with background levels of radiation. Consequently, from their standpoint, it probably makes little difference whether the intrusion scenario intercepts one or twenty waste packages or whether the compliance period is 10,000 or 300,000 years; society should not expend its scarce resources worrying about or trying to address issues such as those.

Having said this, I hasten to add that these transformations may prove to be quite functional after all. The most efficient and perhaps even the most ethical path for disposing of HLW and SNF may be to sidestep the soft questions and focus on the hard answers. But, if that in fact is the case, we probably should take that detour self-consciously and deliberately and not thoughtlessly or by default.

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