U.S. ENVIRONMENTAL PROTECTION AGENCY'S POLICIES ON CONSIDERATION OF HUMAN INTRUSION FOR GEOLOGIC DISPOSAL OF RADIOACTIVE WASTE

B. Forinash
U.S. Environmental Protection Agency, Washington, DC, United States of America

Abstract. In assessing the performance of geologic disposal systems for radioactive waste, human intrusion must often be considered. To assess the potential consequences of human intrusion, it is necessary to define what types of intrusion might occur and when. Over the long time frames considered for geologic disposal, however, it's impossible to predict these parameters with certainty, and assumptions must be made. Numerous reasonable assumptions can be made depending on site factors and available data. This paper examines two different approaches used by the U.S. Environmental Protection Agency (EPA) for considering human intrusion at one operating and one proposed geologic disposal system in the U.S.

1. INTRODUCTION

1.1. Why consider human intrusion?

Considering human intrusion scenarios can be an important aspect of assessing the potential performance of a geologic disposal system. Even where there is not drilling occurring today, the possibility cannot be eliminated that drilling or other activities would occur far into the future near the disposal system. Over thousands of years, societal factors and economic resources may change drastically, and people in the future may drill or conduct other intrusion activities for reasons we can't foresee. Furthermore, while active and passive institutional controls might be effective at warning potential intruders, it may be optimistic to assume that they can endure for time frames on the order of ten thousand years.

In some geologic settings, human intrusion scenarios may also offer the most direct and important pathways for release of radioactive material and subsequent human exposures. Finally, the examination of human intrusion attests to the resilience of the disposal system — that is, its containment capabilities under a variety of stressors.

1.2. The context for considering human intrusion

As noted above, it is not possible to predict the evolution of technology and human behavior over tens of thousands of years. There are a literally unlimited number of possible futures (and associated human activities) that could occur. In assessing the performance of disposal systems, it's not reasonable — or possible! — to model every activity or event that conceivably could occur. Instead, we must limit the scenarios by making some assumptions about the future. In theory, there are also an unlimited number of assumptions available, although in practice it can be seen that some are more plausible than others. Still, there is a range of plausible assumptions which can be adopted.

When deciding how to treat human intrusion, some of the questions to be answered include:

— Should we consider deliberate intrusion into the waste, or accidental intrusion?
— Should we consider acute releases, long-term releases, or both?
— Should we consider individual radiation doses to the intruder?

In addition to such questions, one must define the type, location, and timing of any intrusions to adequately assess the potential consequences.
1.3. Two approaches to consideration of Human Intrusion

This paper shows two possible approaches based on different types of assumptions about human intrusion in the future. The paper examines two geologic disposal systems regulated by the U.S. EPA: the Waste Isolation Pilot Plant (WIPP) and the proposed Yucca Mountain disposal facility.

The WIPP, located in the southwestern U.S., is already in operation for the disposal of transuranic waste. Waste is located nearly 655 meters (2150 feet) underground in bedded salt deposits. Significant drilling and mining now occur near the facility, and economically viable mineral resources are located immediately above the disposal system. Pressurized brine pockets beneath the repository also could provide a driving force to move waste up a borehole if a drilling event were to puncture a waste drum and continue deeper below the waste rooms.

The Yucca Mountain site is proposed for disposal of spent fuel and high-level radioactive waste, but has not been fully built nor licensed for operation. The site is located in a desert climate in the western U.S. Waste would be placed 300 meters below the surface; two aquifers lie another 300 meters below the proposed waste rooms. No mining or drilling occurs in the immediate vicinity of the proposed disposal system. In fact, the U.S. federal government owns much of the surrounding land and access is strictly controlled. Shallow drilling for water occurs intermittently, but the closest known borehole for water is nearly 20 kilometers away.

2. COMMON ELEMENTS OF THE TWO APPROACHES

Relative to the types of considerations outlined in Section 1.3, EPA has made several decisions that apply to both the WIPP and Yucca Mountain.

First, we do not address deliberate intrusion into the waste. We believe it's not possible to prevent a concerted and deliberate — essentially criminal — effort to reach the waste. Focusing on inadvertent intrusion allows us to emphasize controllable factors regarding the disposal system, such as siting choices and engineering design.

Second, we do not consider doses to the intruder. These doses are highly dependent on the specific drilling parameters assumed, and do not therefore provide significant information on the controllable factors discussed above.

Third, long-term releases related to human intrusion are considered for both facilities. All transport and exposure pathways must be considered for long-term releases. For the WIPP, as discussed later, we also consider acute releases associated with potential drilling events.

Finally, for both facilities it is necessary to make some significant assumptions about potential human intrusion in the far future. Current activities — such as those near the WIPP — can be modeled with some certainty, but the same cannot be said for activities several thousand years away.

The subsequent sections of this paper describe the different approaches taken at the WIPP and Yucca Mountain. For each site, the paper describes: the regulatory framework; the general approach and rationale; the type, location, and timing of intrusions; and finally, a discussion of how the consequences are (or will be) considered.
3. THE WASTE ISOLATION PILOT PLANT (WIPP)

3.1. Regulations

EPA's regulations apply to performance over a 10,000-year time frame. The regulations limit the amount of waste released into the environment (activity of each radionuclide, in terms of Becquerels or curies); performance assessments to show compliance with these "release limits" must include both natural events and human intrusion. The regulations also include separate limits on individual doses and concentrations of radionuclides in groundwater. These also carry a 10,000-year regulatory time frame, but apply to "undisturbed performance" of the disposal system, so do not include consideration of human intrusion.

3.2. Approach to intrusion

For the WIPP, EPA adopted a probabilistic approach to the consideration of human intrusion. While uncertainty about the future is unavoidable, we know that drilling and mining has occurred in the past and present near the WIPP. Information on the past history and current practice near the WIPP can be used to assemble a model of potential future human activities near the disposal system.

3.2.1. Type of intrusion

The performance assessment considers the act of drilling a hole to be the relevant event. Drilling characteristics — such as borehole diameter and depth — used in the performance assessment are based on current practice in the vicinity of the disposal system. Activities subsequent to drilling a hole (such as resource extraction) are not considered because these techniques tend to be very specialized and particular to a given resource. Because the existing resources can be projected to be depleted in a small fraction of the regulatory time frame, it was deemed desirable to make the modeling parameters independent of resource type as much as possible.

3.2.2. Frequency of intrusion

The assumed frequency of intrusion is also based on drilling near the WIPP site. EPA requires that performance assessments assume that the rate of drilling over the regulatory time frame will be the same as the rate of drilling near the WIPP over the past 100 years, which accounts for the full available history regarding drilling in that area. The rate is assumed to remain constant for 10,000 years. We believe this is reasonable because, although today's resources may become depleted or become less valuable, other resources may be discovered or may become more valuable over the course of time. EPA did allow the assumed rate of drilling to be reduced based on the presence of active and passive institutional controls, but the assumed effectiveness of such controls was limited to a portion of the regulatory time frame (well under 1000 years).

3.2.3. Location and timing of intrusion

For performance assessment purposes, drilling events over the 10,000-year regulatory time frame are assumed to occur randomly in space and time over the geologic formation — the Delaware Basin — containing the WIPP. Since we don't know what resources will be valuable in the future, it is not possible to predict what exploration patterns will exist. Because of this uncertainty and the fact that the drilling rate (see Section 3.2.2) is based on the entire geologic
formation, EPA decided it would be reasonable to assume that drilling would occur throughout the same area for the performance assessment.

3.3. Consequences of intrusion

Performance assessments for the WIPP must consider immediate releases from drilling events assumed to occur during the regulatory time frame. These can be reasonably accounted for in performance assessment, because the regulations are set in terms of "release limits" for radionuclides. A drilling borehole can provide a direct pathway for releases of radioactive materials to the accessible environment; mechanisms for release include cuttings/cavings and spallings, and at the WIPP, pressurized brine releases if a borehole hits a brine pocket after penetrating a waste drum.

Long-term releases must also be included in performance assessments. All transport and release pathways are considered. Performance assessments must account for degradation of sealed boreholes and for potential fracturing caused by human intrusion.

3.4. Results of analysis

Since the certification (licensing) of the WIPP facility has been completed, it is possible to examine the results of performance assessments that include consideration of human intrusion.

First, although not the focus of this paper, it is noteworthy that there was significant public interest in current drilling and mining activities near the WIPP. Concerns were raised about the potential for these activities to cause fracturing and affect transport of radionuclides. Based on these concerns, EPA required detailed analyses of many current practices, including some highly specialized extraction techniques. None of these activities was found to affect the WIPP's performance.

Based on performance assessments, drilling scenarios in the far future were responsible for the greatest potential releases from the disposal system. Not unexpectedly, the largest of these releases occurs if a drill is assumed to intersect a waste package. However, even taking into account potential releases from human intrusion, the WIPP met EPA's requirements by several orders of magnitude.

4. THE PROPOSED YUCCA MOUNTAIN DISPOSAL FACILITY

4.1. Regulations

Like the WIPP regulations, EPA's regulations for Yucca Mountain apply over a 10,000-year time frame. However, they are structured very differently. The Yucca Mountain requirements include a separate analysis of human intrusion rather than examining it as part of a broader performance assessment. The analysis of human intrusion must consider the same receptor location and characteristics as for undisturbed performance (accounting for only natural events) and must meet the same dose limit (150 microsieverts). Note that the dose limit applies only if the intrusion event is assumed to occur within 10,000 years after closure of the repository. If the event is postulated to occur after that time, the analysis must be completed and included in the licensing application for informational purposes, but releases are not compared to the numerical limit.
The regulatory approach to human intrusion at Yucca Mountain follows closely the recommendations of the U.S. National Academy of Sciences. While developing regulations, EPA asked the National Academy to provide expert guidance on the technical basis for several issues. The consideration of human intrusion was one of these issues of particular interest to EPA.

4.2. Approach to intrusion

In contrast to the probabilistic approach used at the WIPP, the Yucca Mountain regulations adopt a deterministic approach to human intrusion. While uncertainty about future activities is still unavoidable, at Yucca Mountain there is no history of drilling near the facility that could serve as a basis for modeling future activities. In the face of this lack of information, we believe it is more reasonable to fix parameters related to the nature and frequency of intrusion, and then examine the potential consequences. We believe that examination of a single such "stylized" intrusion event can still provide key information about the containment capability of the disposal system.

4.2.1. Type of Intrusion

For Yucca Mountain, the characteristics — borehole diameter, borehole depth, etc. — of the stylized intrusion event are based on the current practices in drilling for water. This is the most valuable known resource near the disposal facility, although the nearest drilling for this purpose is 20 km from the disposal system.

4.2.2. Frequency of intrusion

A single drilling event is assumed to occur (with a probability of 1).

4.2.3. Location and timing of intrusion

In order to provide information directly relevant to the performance of the disposal system, the drill is assumed to be located immediately above the repository. The drill is assumed to penetrate a waste package and then reach an underlying aquifer.

EPA requires that the intrusion be assumed to occur as soon as waste packages degrade enough that drillers would be able to recognize the waste. This requirement assures that the analysis does not assume that drillers will take action to mitigate the consequences of the intrusion. The precise timing of the intrusion will be established by the licensing agency (the U.S. Nuclear Regulatory Commission) based on an analysis of waste packages and other factors.

4.3. Consequences of intrusion

For Yucca Mountain, immediate releases from drilling are not considered. Such releases are more dependent (than long term releases are) on the specific drilling parameters assumed in the analysis rather than on disposal system characteristics. Unlike the WIPP, there is very little information on drilling practices nearby. Therefore, the uncertainty in fixing parameters is greater and we decided not to consider immediate releases through the borehole.

The analysis must consider long term releases through all pathways, and must account for the degradation of sealed boreholes. The resulting releases account only for material in the waste package assumed to be penetrated by the drill. Releases from other undamaged containers are
not considered in conjunction with the human intrusion analysis, nor are unlikely natural events.

4.4. Results of analysis

The results of the analysis are not yet available. The U.S. Nuclear Regulatory Commission (the licensing agency for Yucca Mountain) is expected to provide additional guidance on how the analysis should be conducted and will examine the results.

5. CONCLUSIONS

As has been discussed, EPA has used very different approaches for consideration of human intrusion. Several conclusions can be drawn by examining the divergent scenarios that EPA has presented.

There is great unavoidable uncertainty regarding technological changes and human activities that might occur over 10,000-year time frames, or longer time frames, considered for geologic disposal. To reduce speculation about future scenarios, it is necessary to make assumptions about what human-initiated events might occur in the future to disturb the disposal system.

All such assumptions are arbitrary to some degree, and the scientific support for them open to debate. One must consider what approaches are conceivable and what information is available to justify each of the approaches. The selection of assumptions should take into account the surroundings of the site, including the geologic setting, the status of current drilling or other activities, and what uncertainties exist about different aspects of disposal system performance. In addition, it is reasonable to consider whether different or more detailed human intrusion analyses should be conducted to account for heightened public concern on the issue. Further information on EPA's regulations for WIPP and Yucca Mountain, including the human intrusion requirements, can be found on EPA's web page at www.epa.gov/radiation.