

## Performance Monitoring and Retrievability of Emplaced High-Level Radioactive Waste and Spent Nuclear Fuel in Geologic Repositories

Bret Leslie and Roberto Pabalan

*U.S. Nuclear Waste Technical Review Board*

### Summary

*The U.S. Nuclear Waste Technical Review Board (Board) held a meeting in March 2018 to review information from several international repository programs related to (i) operational and performance confirmation monitoring of a geologic repository for high-level radioactive waste (HLW) and spent nuclear fuel (SNF) and (ii) retrievability of emplaced HLW and SNF. Based on the presentations given at the meeting, the Board generated observations related to the implementation and monitoring of geologic repositories and the retrievability of emplaced HLW and SNF. These observations address (i) initial repository design, (ii) the integral nature of monitoring to repository development, (iii) monitoring objectives and limitations, (iv) the role of underground research laboratories and repository pilot facilities, (v) monitoring and sensor technologies, (vi) a stepwise approach to repository development, and (vii) knowledge transfer.*

### Introduction

Worldwide, there is strong consensus on the value of a stepwise approach to repository development and licensing where the implementer and regulator periodically assess whether the proposed disposal concept and repository design can meet health, safety, and environmental requirements. Two actions are integral to the success of such an approach: first, successful monitoring of the repository, and second, retaining the option to retrieve the emplaced waste, if necessary.

On March 27, 2018, the Board<sup>1</sup> met to hear the views of international repository experts on challenges intrinsic to both monitoring and waste retrieval. The meeting participants were asked to address three overarching questions:

- What are the requirements for undertaking operational and performance confirmation monitoring and retrievability?
- What are the potential technical and institutional challenges involved in carrying out those activities?
- What lessons can be learned from international programs that can be applied to the U.S. geologic repository program?

The Board also heard from subject matter experts on sensors and technologies for monitoring subsurface seepage and waste package corrosion in a geologic repository. These two topics are part of the 20 performance confirmation activities that the U.S. Department of Energy (DOE) identified in its license application for the Yucca Mountain repository (DOE 2008). The meeting agenda, the presentations, the

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<sup>1</sup> The Board was created by the U.S. Congress in the 1987 Nuclear Waste Policy Amendments Act (Public Law 100-203) and charged with evaluating the technical and scientific validity of activities undertaken by the Secretary of Energy to manage and dispose of HLW and SNF. The Board reports its findings and recommendations to Congress and the Secretary of Energy.

transcript of the proceedings, and an archived webcast of the meeting are available on the Board's website at <http://www.nwtrb.gov/meetings/past-meetings>.

The Board used the information provided by repository experts from France, Switzerland, Belgium, and Germany, as well as the subject matter experts, to develop observations. The Board summarized the meeting and presented and discussed its observations related to repository monitoring and retrievability of emplaced HLW and SNF in a report to the U.S. Congress and the Secretary of Energy (NWTRB 2018).

### **Board observations**

Based on the presentations given at the meeting, the Board generated seven observations related to the implementation and monitoring of geologic repositories and the retrievability of emplaced HLW and SNF. These observations address (i) initial repository design, (ii) the integral nature of monitoring to repository development, (iii) monitoring objectives and limitations, (iv) the role of underground research laboratories and repository pilot facilities, (v) monitoring and sensor technologies, (vi) a stepwise approach to repository development, and (vii) knowledge transfer. The Board's observations and some discussion of each observation are presented in the following subsections.

#### ***Initial repository design***

The Board observed that:

- Retrievability is an important consideration in the initial repository design, adding only a small increment to the cost of repository development but offering substantial cost reduction if retrieval is determined to be necessary.

There was general agreement among the speakers at the meeting that it is important to incorporate features into the initial repository design that will facilitate waste retrieval if that is deemed necessary. An example of the consequences of failure to do this comes from the Asse II salt mine in Germany, where low- and intermediate-level radioactive wastes were disposed of between 1967 and 1978. Retrieving the emplaced radioactive waste at Asse II is challenging because of uncertainty associated with the current conditions of the waste and the emplacement chambers, and because no thought had been given to possible retrieval at the time that waste was being emplaced in the mine.

It is recognized that waste retrieval becomes more difficult and costlier as implementation of the repository program progresses (OECD/NEA 2012). But according to the speakers at the meeting, there are measures that can be taken to enhance, or at least not impede, retrievability. The Board recognizes that there can be trade-offs between design features that facilitate retrievability (and monitoring) and those that might enhance long-term containment of wastes or that promote safety and efficiency of operations prior to repository closure. The Board was encouraged to hear from several of the presenters that some countries have come up with options to address these trade-offs, for example, by using backfill materials that can be easily removed after waste emplacement if wastes must be retrieved.

#### ***The integral nature of monitoring to repository development***

The Board observed that:

- Monitoring to assess operations and to support decisions related to repository operations or waste retrieval is also an integral part of repository development.

Information provided at the meeting shows that monitoring activities to generate the data required for a decision to modify operations or retrieve waste should not be simple add-ons to a repository program. The speakers recommended that these activities should be integral to repository development

and must be considered in the early design stages of the repository program. Taking account of monitoring early in the repository program enables planning for and conducting the research, development, and demonstration activities of sensors and technologies required for monitoring. Throughout the development of a repository as well as through operations, the monitoring program needs flexibility to address spatial and temporal variability in properties and processes and the ability to replace or retrieve sensors (in some cases using robotic or other remote handling capabilities) or to incorporate new sensor technologies as they evolve and improve.

### ***Monitoring objectives and limitations***

The Board observed that:

- It is essential that the monitoring objectives and limitations are understood, the indicators that will signal the need for a modified path or retrieval are transparent, and the collected data are broadly accessible to enhance public trust and for use in performance confirmation modeling by the implementer and other stakeholders.

The speakers at the meeting acknowledged there are limitations to what can be monitored. Thus, in the Board's view, the implementer needs to be open about the objectives, strengths, and limitations of monitoring so the public understands what monitoring can and cannot accomplish. Transparency and making the monitoring and other data available to the public may enhance trust and build credibility. The Board believes that the implementer, in developing a monitoring program, needs to clearly define the "thresholds" for action, i.e., the monitoring results or other indicators that will signal the need to start considering and possibly implementing plans for a modified path forward or retrieval based on repository modeling results obtained as part of performance confirmation.

### ***The role of underground research laboratories and repository pilot facilities***

The Board observed that:

- Underground research laboratories and repository pilot facilities improve the technical basis and confidence in the future success of monitoring technologies and potential retrieval, and can serve as demonstration sites to build public acceptance.

The Board considers that useful "tools" to provide information needed to make decisions on monitoring and retrievability include (i) underground research laboratories, which may be generic or near the site of a proposed repository and (ii) pilot facilities, which may be areas within a repository that are monitored intensively as an alternative to attempting to monitor the entire repository. These facilities allow the testing and demonstration of waste emplacement, waste retrieval, and monitoring technologies in prototypical environments. These test activities can greatly improve the technical basis and confidence in the future success of the technologies, demonstrate operational safety, and help to find "unexpected" events. Such facilities also can serve as demonstration sites to build public acceptance of the repository.

### ***Monitoring and sensor technologies***

The Board observed that:

- Long-term research, development, and demonstration of monitoring and sensor technologies are needed to address current technology limitations.

The meeting presentations on monitoring and sensor technologies indicate techniques already are available for measuring most of the key parameters of interest in repository performance confirmation. However, most existing sensors have relatively short lives, make point rather than spatially distributed

measurements, are designed for near-surface applications, lack the ability to self-calibrate, show long-term instrumental drift, require power for long-term operation, and need to be radiation- and heat-hardened. Work to improve currently available technologies will take a sustained research, development, and demonstration program over many years. In the case of unsaturated zone monitoring, technology needs to be developed to measure moisture content and matric potential, two properties used to estimate seepage flux, continuously over long distances and at greater depths and harsher (high temperature, high radiation) environments than at the relatively shallow depths for which current sensors have been developed. There has been rapid development of sensor technology that may be applicable to waste package corrosion monitoring based on advances in material science and nanotechnology. However, the long-term stability of these sensors needs to be studied.

### ***A stepwise approach to repository development***

The Board observed that:

- A stepwise approach to repository program implementation and decision making is important because it provides opportunities to reassess decisions and modify future plans.

The experience of European countries in implementing repository programs, summarized by several of the meeting speakers, demonstrates that in a discrete, stepwise approach, the regularity of decision making (e.g., periodically updating the safety documentation or the research, development, and demonstration program) facilitates systematic re-assessment of the program over time and allows potential changes on a regular basis. Smaller steps mean more frequent engagement between the implementer, the regulator, and the stakeholders. Stepwise and flexible decisions, as well as incorporation of improved technologies during development and operation of a repository, may be easier to achieve when they are explicitly incorporated into the licensing/approval process.

### ***Knowledge transfer***

The Board observed that:

- Measures are needed to facilitate knowledge transfer to future generations so that expertise is available to access and interpret monitoring data.

Given the long period of repository operations and pre-closure monitoring, the Board believes that particular effort is needed to develop institutional and other mechanisms to ensure the transfer of relevant knowledge, the capability to apply that knowledge, and the sustainability of stewardship into the future. There is a need to ensure adequate scientific and engineering talent, for example, by engaging younger generations in nuclear waste management issues, training them in the nuclear field, and enhancing nuclear-related research. Emphasis should be placed on expertise to develop, maintain, and interpret sensor data and to maintain data cyberinfrastructure.

### **Conclusion**

The Board reflected on the information presented at its March 2018 meeting and considers it clear that repository programs in other countries offer lessons related to the implementation and monitoring of geologic repositories and the retrievability of emplaced HLW and SNF. The Board recorded its observations in its report following the meeting (NWTRB 2018), with the objective of informing DOE's activities when DOE moves forward with a program for geologic disposal of U.S. HLW and SNF.

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## References

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- U.S. Department of Energy (DOE) (2008), *Yucca Mountain Repository License Application*, DOE/RW-0573, Las Vegas, Nevada.
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