Editor's Message

Regulating the long-term safety of radioactive waste disposal: Time for hydrogeologists to communicate and participate

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Radioactive wastes containing large amounts of long-lived radionuclides require long-term isolation. Although fraught with technical, social, and economic problems, disposal in deep continental geological formations is the preferred option for solid long-lived and high-level waste in all countries with nuclear technology programmes. Considerable progress has been made in the last two decades in demonstrating that geological disposal is feasible and safe, but this progress has been poorly communicated. Hydrogeologists have both an opportunity and an obligation (1) to participate in the waste management and regulatory activities and in their critical and independent review; (2) to help improve communication among scientists, implementers, and regulators; and (3) to help convey the concept and improve understanding among the public, environmental groups, and politicians.

The concept of geological disposal requires construction of a mined shaft and tunnel network; emplacement of the conditioned wastes encapsulated and packaged in metal canisters; and backfilling and sealing the emplacement holes, tunnels, and shafts with materials chemically and physically compatible with the rock and waste packages. The safety of the concept is warranted through the functioning of a multi-barrier design, e.g., waste form, canister, buffer, and geologic media. These barriers are designed to achieve a maximum degree of independence and redundancy in their safety functions.

Important features of the multi-barrier disposal concept are that it is passive and flexible, i.e., it does not require continuing human involvement for its safety, and a variety of geological environments and engineered designs are believed to be suitable for disposal.

Considerable progress has been made to demonstrate that geological disposal is also feasible and safe:

- The quality of a selected site and design is one of the key elements that provide safety to an underground repository. Methods for an adequate site characterization and engineered design have been developed, applied, and documented. Many national repository development programmes are shifting from a

research phase to a development phase. Various types of host rocks (crystalline rocks, clays, shales, salt, and volcanic rocks) and complementary engineered barriers to isolate the wastes from the biosphere are envisaged in the different national programmes.

- Activities to demonstrate the feasibility of geological disposal are being performed in underground research laboratories in argillaceous rocks (Belgium, France), crystalline rocks (Canada, Finland, Japan, Sweden, Switzerland), salts (Germany, USA), and unsaturated tuffs (USA).
- Integrated performance-assessment (PA) and safety-assessment (SA) studies completed in these countries are aimed at demonstrating the safety of the concept of geological disposal. These studies provide: (1) quantitative analyses of a set of processes identified as relevant to the performance of a subsystem or the disposal system; (2) calculations of some measures of performance (thermal evolution, contaminant release from a subsystem); and (3) comparisons of calculated measures with design targets and regulatory limits. A PA becomes a SA when the system under consideration is the overall disposal system and the performance measure is radiological impact or some other global measure of impact on safety (individual dose, integrated total release of contaminants).

PA and SA results have been used to provide research and development guidance, to give support to site selection and repository design, to assist with the formulation of regulations, and to support decisions to proceed from a repository-development stage to the next phase. An example of a good and successful PA study aimed at licensing is the PA that is included by the U.S. Department of Energy (DOE) in the Compliance Certification Application for the Waste Isolation Pilot Plant (WIPP), a repository recently opened for the disposal of transuranic radioactive waste in New Mexico, USA. After a review of the project, the U.S. Environmental Protection Agency (EPA) released its final certification in May 1998. The first shipment of waste arrived at WIPP in early 1999.

The studies made by the DOE and EPA provide evidence that it is possible to build repositories that can be considered safe for man and his environment.

SA of geological disposal entails some difficult questions about hydrogeology and related disciplines. Important scientific and technical developments have been made in order to address these questions. Here I refer to the progress made in the development and testing of: (1) site-characterization methodologies at different scales; (2) techniques to handle, trace, and integrate structural, hydrogeological, and geochemical data in several alternative geological models; (3) techniques to test the consistency of conceptual models of fluid flow in low-permeability environments, heat and mass transport, and water-rock interactions; (4) techniques of uncertainty and sensitivity analysis to be applied to parameters, models, and scenarios; (5) quality-assurance methodologies to be applied to the design, construction, and operation of repositories; and (6) the training of multidisciplinary teams.

However, this progress has been poorly communicated, even within the scientific community. Regulating the safety of the disposal of radioactive waste may be one of the least known activities of repository-development programmes. The main responsibilities of regulatory bodies are to define the safety and radiation-protection criteria; to issue guidance on safety-assessment methodology; to review the safety assessments performed by the organizations responsible for the management and disposal of radioactive waste (the implementers), as a basis for licensing of disposal activities and facilities; and to inspect and review construction and operation of disposal facilities to ensure compliance with the licensing conditions.

Hydrogeologists will find challenging tasks in most of these regulatory activities:

- Criteria by which a disposal option can be judged to provide an acceptable level of safety involve principally the levels of individual risk to health from exposure to radiation. The development of disposal systems includes a complex set of activities with associated short-term (operational) and long-term (post-closure) risks. Standard regulations concerning the protection of workers and environmental monitoring apply in the short term. However, the assurance of radiological safety over hundreds of thousands of years must be based on predictive modeling of the behavior of radionuclides and the repository components. In the long-term, the risks associated with waste disposal will depend on the natural events and processes and on human actions that could cause a release of radionuclides into the biosphere and result in unacceptable radiation doses for the public. Generally, the primary cause of human exposure from a disposal site will be the degradation of conditioned waste and its container and the subsequent transfer and dispersal by groundwater. International

organizations have suggested that radiation-protection criteria expressed in the form of natural radionuclide concentrations in groundwater can be considered an appropriate safety indicator, when combined with dose/risk criteria.

- The general approach to SA and its subsequent regulatory review include several steps in which hydrogeological issues arise:
 1. detailed description of the disposal system;
 2. identification and selection of scenarios illustrating and representing a variety of possible futures that could affect repository safety;
 3. description of the conceptual models, key assumptions, and mathematical models used for consequence analysis;
 4. description of the uncertainty- and sensitivity-analysis techniques; and
 5. comparison of the results with the design goals and the regulatory criteria.

The geological-disposal option involves not only technical but also political and social issues. Technical experts working in such an interdisciplinary area as geological disposal have already been faced with the challenge to maintain a high level of communication among themselves. Perhaps a bigger challenge to be faced by these experts will be to understand and answer the concerns of the general public, environmental groups, and politicians. The community of radioactive waste management is already exploring, developing, and applying techniques for addressing the needs of the public and other non-technical stakeholders. The expectation is that this strategy will ease the way to get the proposed repositories technically assessed and reviewed as well as socially accepted.

International organizations such as the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA), the International Commission on Radiological Protection (ICRP), and the European Commission (EC) provide a reference framework in which all these aspects of geological disposal are debated in a transparent way. They have a responsibility of the utmost importance to enhance the dialogue between implementers and regulators, to identify points in common, and to derive recommendations for further work. Hydrogeologists must play a leading role in these activities.

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