

Interregional Training Course on Radioactive Waste Disposal Technologies - 9536

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ABSTRACT

An interregional course sponsored by the International Atomic Energy Agency (IAEA) on radioactive waste disposal technologies for geologic disposal in North America was recently completed. The IAEA recognizes that the status of waste management is very different among countries operating nuclear power plants. Countries with large nuclear programs are generally more advanced than others with smaller inventories or with less organized structures. It is in the interest of all the countries engaged in the production of nuclear energy to promote and facilitate nuclear waste management worldwide. The IAEA therefore established a training program under its Technical Cooperation Program, beginning in 2003. The objective of this program is to transfer knowledge and technology from Member States with advanced research and development programs in underground research facilities by training specialists from Member States with less developed repository implementation programs and/or having no direct access to underground research laboratories.

Sandia National Laboratories, in its unique role as the Science Advisor for the Waste Isolation Pilot Plant (WIPP) since inception and more recently as the United States Department of Energy (USDOE) Office of Civilian Radioactive Waste Management Lead Laboratory for Repository Systems, organized the most recent course at the behest of the IAEA and the USDOE. The Canadian program was extensively represented, as the interregional course embodied North American Underground Research Laboratories and waste disposal technologies. Field trips were made to the operating WIPP facility and the Yucca Mountain exploratory studies facility. Technical presentations and discussions covered an extensive array of topics, including regulatory framework, site selection, natural and engineered barriers, and risk assessment. This paper explores the technical content of the course, as well as the feedback from the international participants. Additional information can be obtained on the course website http://www.sandia.gov/IAEA/IAEA_Home.html.

INTRODUCTION

Nuclear waste disposal is an international issue of increasing importance. The path to disposal often includes underground research laboratories and demonstration facilities. This paper shares international reflections on the topic of Underground Research Laboratories (URLs), particularly from the perspective of emerging nuclear Member States. A two-week training course on North American geologic disposal was completed over the period November 3-14, 2008. The course was sponsored by the IAEA and hosted by the USDOE and Sandia National Laboratories. The course was strongly supported by the Canadian nuclear programs. We recount the material presented by technical experts, workshop topics, site visits (URLs and others), and pay particular attention to arising issues of the participants from Member States. As the course progressed, we sought real-time evaluations and constructive criticism for course content

and potential improvement. This feedback also helped identify primary issues confronting geologic disposal in the participating Member States.

PARTICIPANTS

The hosts for this course on radioactive waste disposal technologies are the IAEA, USDOE and Sandia National Laboratories. The IAEA was responsible for selecting viable representatives from the Member States with less developed repository implementation programs. The two-week program discussed in this paper transferred knowledge and technology from URL programs in North America by training specialists from Member States. The USDOE, working in agreement with the IAEA, has arranged for the technical programs with assistance from national laboratories and representatives from the Canadian programs. This year Sandia National Laboratories was asked to develop technical course material and arrange site visits.

Participating countries included South Africa, Slovakia, Romania, Mexico, Slovenia, Czech Republic, Russia, Kazakhstan, and Philippines. Including hosts, twelve nations participated in this two-week course. Although this training course does not represent a scientific survey, the dialogue and feedback from this interaction are germane to the international status and viability of URLs.

AGENDA

The objective of this program as captured in the IAEA mission statement is to transfer knowledge and technology from Member States with advanced research and development programs in underground research facilities by training specialists from Member States with less developed repository implementation programs and/or having no direct access to underground research laboratories.

A broad agenda was arranged to address the mission statement of the IAEA. Some 34 technical presentations were made by 31 different subject matter experts. A biographical sketch of each presenter and a link to the presentation are provided on our course website http://www.sandia.gov/IAEA/IAEA_Home.html. Repository sites and URL visits to WIPP and Yucca Mountain provided direct physical appreciation of two deep geological disposal options in the United States. Much of the course material presented to the international participants derived from long-term site characterization activities conducted by these two programs. The counterparts from Canada provided similar technical experience from their comparable decades of scientific inquiry in URLs.

A review of North American URL experience includes significant breadth and depth of potential subject matter. Therefore, many choices were possible when the course curriculum was developed. Topical areas were selected by the hosts, based on their collective knowledge, to emphasize certain developments, events, criteria, scope, science, and perceptions out of numerous possible considerations.

The course instruction topics emphasized:

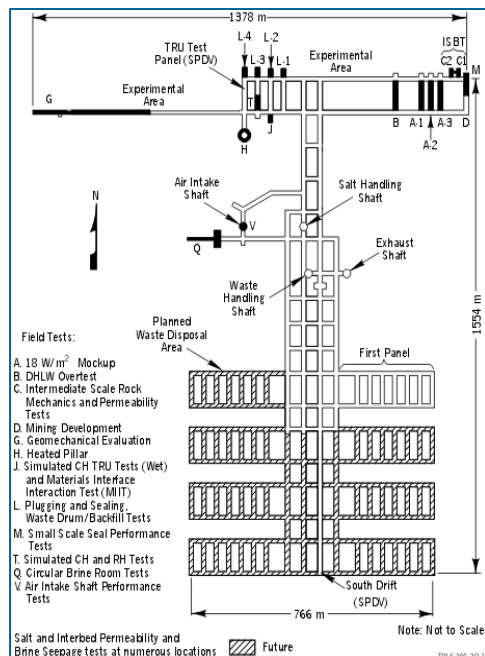
- Regulatory framework
- Site selection
- Repository design considerations—also workshop topic
- Site characterization— also workshop topic
- Modeling—thermomechanical, fluid flow, radionuclide transport
- Natural and engineered barriers— also workshop topic
- Features, Events and Processes

- Performance assessment/risk assessment
- Performance confirmation and monitoring
- Licensing

One day each was dedicated to site visits to WIPP and Yucca Mountain. Other afternoon and evening venues were included for interactions with a host community and pertinent scientific field trips. Three group exercises were conducted on repository design challenges, issues concerning URLs/site characterization, and engineered barriers, respectively. Site visits were deemed most beneficial at the outset, augmented with traditional lectures by subject matter experts. As the course progressed, the hosts sought and received objective feedback on the utility of each day's material.

VISIT TO WIPP

The Waste Isolation Pilot Plant is an operating nuclear waste disposal facility (www.wipp.energy.gov). The processes of site selection, characterization, licensing and operations were shared with the international group. WIPP is situated in an enormous salt formation (Salado), which has many positive attributes for isolation—such as impermeability, ease of mining, and plastic deformation. The WIPP project was conceived as a pilot plant in the 1970's and thus began as a site-specific URL that accommodated a sophisticated suite of site characterization experiments. Because the WIPP URL was conjoined with the now-operating repository, the science experiments were site specific and directly relevant to the repository. Co-location of the URL with the potential disposal site provided significant advantages, as highlighted during the course discussions. Co-location would be an important consideration for emerging programs, as siting and characterization programs are developed.



The WIPP has enjoyed successful operations since 1999. The facility has received over 7000 shipments, which amounts to 58,000 cubic meters of defense-related transuranic waste. Over 108,000 containers have now been placed in the first four panels of the WIPP facility, which is illustrated in Figure 1. Figure 1 also provides a glimpse of the several experiments conducted as part of the URL site characterization studies. As of this writing, the fourth panel is nearly full and a fifth panel has been excavated (out of a design total of ten). The IAEA participants were able to see active waste receipt, transport in the underground, placement in the disposal room, and a few of the experimental areas. Course material described the WIPP as a URL, site characterization, the regulatory process, certification and recertification, and the significance of a

“volunteer” site. The participants, shown in Figure 2, met with community leaders for discussions of the direct benefits and derivatives for a community hosting a nuclear waste repository.

FEEDBACK ON WIPP VISIT

As might be expected, the visitors were very impressed with the WIPP enterprise, which was showcased by

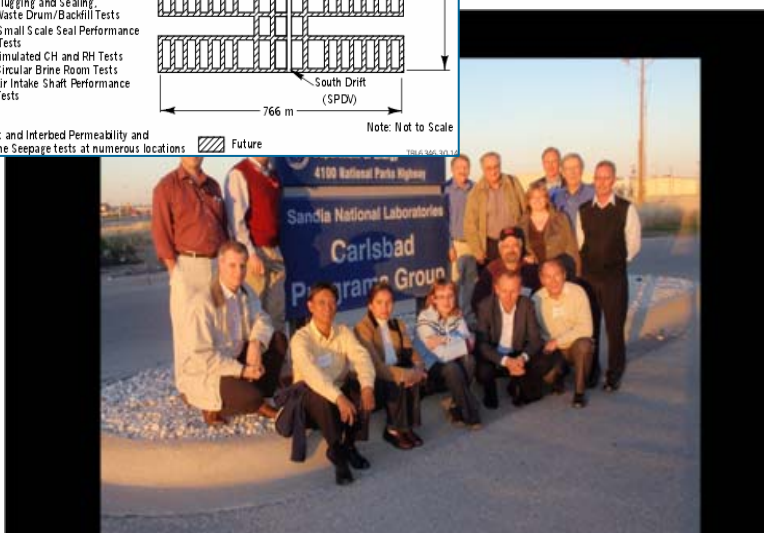


Figure 2-Participants at Sandia's Carlsbad Programs Office

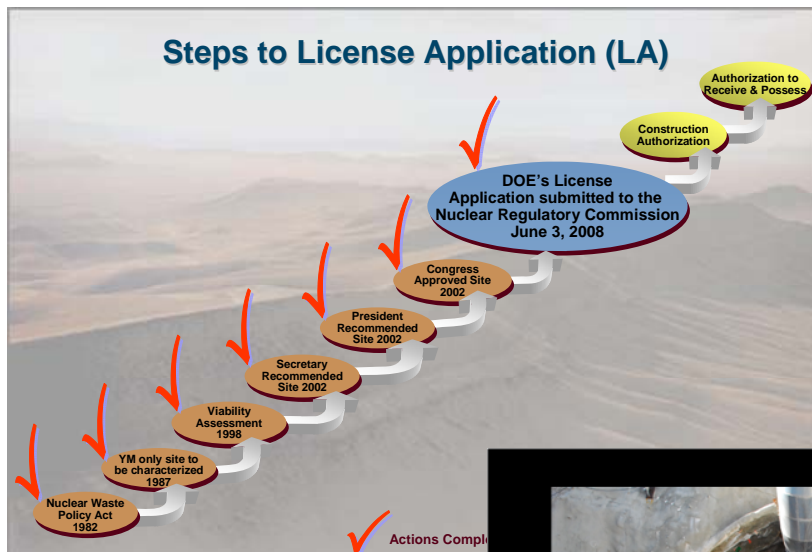
a tour of the waste-handling facilities above ground and the disposal operations below ground. The feedback noted the visit as *historical* and *spectacular*. The participants were unanimous that the site visit conveyed much more information than possible by class-room presentations because it added a physical understanding to the setting and operations. For several participants, the WIPP site visit was their first direct exposure to an operating disposal facility. The IAEA course material was thereby greatly enhanced by the introduction to in situ, real-world materials and methodologies.

Constructive feedback suggested that the course could benefit from additional discussion of the WIPP waste acceptance criteria to understand how the outcome of the performance assessment was incorporated into the practical operations of waste acceptance. At this early stage in the IAEA class, it was not yet made clear which other potential geologic settings were considered or could be used as repositories; this information was presented in subsequent course material. The site visit prompted questions regarding modeling, boundary conditions, and computer code validation. As will be noted later, a site visit in advance of the bulk of the technical presentations helped enormously when the class-room material was presented. To create a balance between field trips and class-room instruction, some participants asked for supplementary upfront information of site geology, including a geological map.

In addition to the real-world aspects of the site tour, the information conveyed on the regulatory requirements and history was thought to provide valuable background for developing a legal framework in their home countries. One participant summarized the site visit thusly: *To see; to learn; to be in (the) repository is the best way to know more about DGR (deep geologic repositories).*

VISIT TO YUCCA MOUNTAIN

Progress toward a construction authorization for Yucca Mountain is illustrated in Figure 3. USDOE



submitted a license application on June 3, 2008, which was docketed by the Nuclear Regulatory Commission (NRC) on September 8, 2008. The NRC will conduct extensive technical reviews of the license application. One or more Atomic Safety and Licensing Boards will conduct hearings that generally will be open to the public. A construction

Figure 3-Steps to License Application

authorization will be granted only if the NRC concludes that the repository would meet all regulatory requirements.



In view of the licensing progress realized over the past year or so, operations at the exploratory studies facility at Yucca Mountain have decreased. Recently, tunnel access and site activities were minimized. Thanks to significant effort and support of the USDOE, the international participants were able to view the Yucca Mountain area on the Nevada Test Site, to visit the Sample Management Facility, and to go underground at the exploratory studies facility. The photograph in Figure 4 is taken at the north portal, from which access was possible to Alcove 2—some 200 m inside the mountain.

FEEDBACK ON YUCCA MOUNTAIN VISIT

As with the WIPP experience, the visit to Yucca Mountain was considered vital to the course. One comment noted: *(the visit) was a highly important component of the training course and gave us, the participants, ground-truth experience of a high-level nuclear repository.* Members of the tour were able to access the mountain crest, where the full panoply of the geologic setting was appreciated. Even the limited access to the Yucca Mountain underground was fundamentally important to conveying the magnitude of the project to the international participants.

Although the visit to Yucca Mountain represented significant effort on the

Figure 4-IAEA Participants at the North Portal of Yucca Mountain

part of the hosts of the IAEA course, there were several suggested improvements for this venue. Participants asked for more specific background on the geology, including a geologic map and stratigraphic profile. This particular suggestion indicated that the tie between the field-trip material, site characterization, modeling, and performance assessment could have been stronger. Others thought *the tour was a very applicable and truly a remarkable learning experience that brought the theoretical and practical aspects closer together. It will give more meaning and deeper insight into presentations and how the safety case was developed.*

WORKSHOPS

The training course sought to achieve a balance between traditional lectures and group-participation activities. To accomplish the latter, three group discussions were developed. The first workshop concerned repository design challenges, the second focused on key challenges for URLs in the participating nations, and the third explored engineered barriers.

Repository Design Challenges

Citizens of Member States applied for acceptance into this course through the IAEA. The IAEA evaluated and selected the successful applicants. Given the course mission statement and assumed suitable qualification of each Member States' representative, it was surmised that each participant was grappling with repository issues within their national framework. As a part of this course, we elicited from the participants their perceived greatest challenge facing their nation's geologic repository future. In compiling the key challenges listed below, the group offered general suggestions and ideas toward solutions as follows:

1. Capacity and skill of engineers and scientists. Possible solutions may involve international outreach, cooperatives, IAEA, and partnership with universities to establish related skills.
2. Political strategy and policy for creating an agency with a clear path leading to site selection. Possible solution may be to examine established programs (e.g., Sweden or Switzerland) for creation of such policy.
3. Small national effort, insufficient resources, low priority. Possible means to address this issue would be to join with other programs and leverage resources via center-of-excellence concepts.

4. Establishment of a national agency for radioactive waste in order to propose a site for geologic disposal (e.g., Pena Blanca) and initiate site characterization studies. A constructive path forward might be achieved by working with the United States to develop a program whereby Mexico (originator of this comment) establishes a fuel exchange-waste management agreement.
5. (Lack of) consistent repository approach for low, intermediate, and high level waste. For countries struggling with basic approaches for a spectrum of waste streams, it is perhaps vital to stay involved with international collaboration.
6. Production of new deep geologic repository. Progress toward geologic disposal is the purpose of this IAEA course. Emerging from class discussion is a concept developed in stages, starting with a transparent national policy, investigating military domains, while seeking volunteer sites and hosting site competition.
7. The future of waste involves near term national policy. This particular comment recognizes that the future of waste programs in some Member States will involve trading resources with neighbors.
8. Historical problems, especially the magnitude of the issue and the duration. Perhaps for the largest problems, a regional strategy for high level waste disposal near the generator site has the best possibility for success, because the population is informed. As noted by our participants: *informed ≠ approval*. Possible follow-up might include an expert mission from the IAEA.

It is interesting to contrast the above challenges with the key design issues of more advanced programs, which include function, performance, environmental, reliability, maintainability, inspection, safety, constructability, operability, and regulatory requirements, codes and standards. Design issues in advanced programs include natural and engineered barriers, waste emplacement method, excavation method, surface and underground infrastructure, regulations, safeguards and security, retrievability, and monitoring.

This exercise illustrates some key differences between emerging programs in geologic disposal of nuclear waste and those of more mature programs. It also serves to point out that some issues persist as programs mature—such as policy matters and political issues. A first observation is that advanced national programs have examined many of the scientific underpinnings for repositories. A large body of knowledge exists on design issues from advanced programs, which might be of value to emerging nations. However, from the dialogue with the participants, their key issues pertain to national history, policy, politics and resources. An overriding hope of the participating nations is that their country could develop a national policy and allocate sufficient resources for a sustained program.

Challenges for URLs

Participants from emerging nuclear Member States typically must optimize their positions owing to limited resources, limited experience, and perhaps limited inventory of nuclear material destined for disposal. Open discussion was engaged on what the participants viewed as their key challenges regarding URLs. Here the challenges are posed as questions, for which the group proposed a fundamental answer.

Question 1: What is the status of a URL and what is the optimal amount of time for research?

Answer: A URL must meet acceptable standards and time of operation would be as long as possible.

Question 2: How does one select a site, define research facility criteria and underground information needed when surface information is limited? Answer: Outreach to other URLs, access information available from entities who have engaged in such work previously, and gain from the experience of others (such as provided in this IAEA course).

Question 3: How do you prioritize science? Answer: Applicability, cost, sensibility, and objective methods, such as expert elicitation.

Question 4: What is the most useful information or characteristics determined by URLs? Answer: That which cannot otherwise be obtained from the laboratory or the surface, such as rock mass response and coupled processes.

Question 5: What is the optimal placement of the URL when one has a heterogeneous site? Answer: In the rock most representative of the intended repository.

Question 6: What percent of site characterization comes from work in the URLs? Answer: Characterization science between 50 and 80%; however, for training purposes and stakeholder information the URL provides 90%.

Question 7: How do you select from two good sites with different rock? Answer: Safety, volunteerism, construction viability, economy, public acceptance. One could also reference siting criteria applied by other countries.

Question 8: How are radionuclide measurements made on a large scale and long periods? Answer: Natural gradient tests, well monitoring, age dating, and hydro-geologic models based on draw-down tests.

Question 9: Do you need public acceptance for URLs? Answer: Yes.

The discussions with international participants became more focused as the course matured. As can be surmised from the questions posed above, there was significant inquiry about URLs and site characterization. The challenges expressed in the earlier design exercise concerned policy and politics of how a country might approach repository considerations. Here the participants had received sufficient introductory materials that their questions were more pointed and direct. Participants had moved forward in their thinking to pose questions about site characterization and scientific inquiry that would be supported by URLs.

Engineered Barrier System Panel

As the experience base continued to develop among the international participants, a panel session on engineered barrier system (EBS) became more and more practical. By the time the EBS panel discussion was held, the participants had been exposed to WIPP, where only one engineered barrier was required, to the Canadian URL testing of seal systems, and to Yucca Mountain, where a relatively complicated EBS is currently in the license application. The panel session on engineered barriers was led by four subject matter experts, who presented introductory material in lieu of formal presentations. Emphasis was placed on the North American experience, although reference was made by the panel to the extensive engineered barriers considerations in other countries. The feedback on the EBS panel discussion was quite positive, with some participants indicating this panel discussion was the most useful of the training course. This panel session also allowed the course to specifically address key aspects of engineered barriers for saturated and unsaturated environments.

GENERAL FEEDBACK/CONCLUSIONS

The international participants were very complimentary in their evaluations of the course content and presentation format. The vast majority of invited speakers were given high marks in terms of how the presented material applied to the course objectives and in terms of quality of the presentations themselves. The panel on engineered barriers was universally acclaimed as useful and informative. Site visits to Yucca Mountain and WIPP were fundamentally important to the IAEA mission for this course. The visitors found the comprehensive tour of WIPP extremely valuable because it presents the full gamut of receipt, transport, and disposal operations, as well as in situ characterization experimental areas. The geological setting and program elements of Yucca Mountain were well conveyed on the field trip, which was greatly enhanced by access to the Exploratory Studies Facility.

At the outset of the course, we had a concept for a “country annex” in which each invitee could present an overview of their nation’s status. This group activity was conceived as an opportunity for the international participants to summarize a significant amount of geologic repository information from their country. The idea was to utilize the provided information for a repository design exercise. Instead, this concept segued into a discussion of key repository design challenges—particularly identifying impediments within their respective nations. The exchange of ideas on these problem areas was both interesting and valuable. In a similar vein, discussions of the URLs and site characterization also led to identification of key challenges, with an increasing level of detail. In fact, as the participants increased their individual input, a sense of team building grew. Each successive group exercise was perceived more and more valuable.

The course agenda was extensive and the relationships of the various components were delineated. For example, the path from the international list of features events, to the site characterization activities, to representation in the performance assessment was thoroughly explained. The international visitors requested more detailed information on experimental work associated with site characterization activities pursued in the URLs, and the transformation of the experimental work into numerical models. The concept of a separate modeling course for this purpose was considered of value to the participants.

This particular type of training course for emerging nuclear Member States is of obvious value. A demonstration of the complete evolution of the geologic repository concept provides a significant information basis for each nation’s decision. For those nations beginning the development of regulations, examples used successfully in the United States and Canada can serve as prototypes. The extent to which site characterization was pursued in North America and the associated cost might not be borne by most nations of the world. Therefore, the extent to which emerging programs can benefit from work already completed is a key justification for supporting courses such as this one.

POSTSCRIPT

The IAEA Acting Director for Technical Cooperation wrote these remarks in a December letter to co-author Dr. Abe Van Luik:

The Course was held a part of IAEA Interregional Technical Cooperation (TC) Project INT 9/173 on training in Radioactive Waste Disposal Technologies in Underground Research Facilities, which is intended to help the Agency to meet its major goal of assisting less developed nations to gain the benefits of safe and sustainable solution for the geological disposal of high radioactive waste from nuclear energy.

Feedback from the participants from Member States and the IAEA staff involved show that the Training Course was extremely successful. Both the classroom events and site visits to the Waste Isolation Pilot Plant (WIPP) underground radioactive waste disposal facility and Yucca Mountain Project (YMP) will help Member States to broaden their overview of international perspectives on the geological disposal of high-level radioactive wastes. Particularly the accounting of the impressive, exhaustive, and thorough work that you and your colleagues have conducted helped the participants to understand why underground research facilities are an essential requirement for the development of national programmes.