EU's Esdred initiative

Cooperation between Europe's nuclear nations goes underground in search of practical repository experience. ***By Wolf Seidler and Bernard Faucher***

High-level radioactive waste geological disposal has been studied by various organisations, notably radioactive waste management agencies together with major research organisations, for the last 30 years. The feasibility of such geological disposal, from a scientific viewpoint, has reached a very mature level and this work therefore provides valuable input to subsequent safety analyses.

These feasibility studies must now be complemented with engineering and technological developments in the following areas:

- Repository construction, including underground operations such as shaft sinking, drift excavation and lining, disposal vault outfitting.
- Transportation of waste canisters from surface to underground and their emplacement in the disposal vaults.
- Vault closure and the subsequent backfilling and sealing operations.
- The general layout, both surface and underground, and the management of the various throughputs in a mining and/or nuclear environment.

To identify the key technological issues, a review of the various activities involved in the construction and closure of a repository has been performed with regard to the existing or easily adaptable technologies available within mining, civil and nuclear engineering.

The results of this examination are the following:

- The construction, operation and closure of an underground repository requires not only the well mastered know-how developed so far in conventional mining and civil engineering, but also the specific technological solutions linked to radiological protection and to the operational safety requirements of a nuclear facility.
- One specific area which needs a thorough investigation and subsequent demonstration is the carrying out of nuclear activities underground.

Although disposal concepts vary from country to country depending, for instance, on the type of waste to be disposed of and the nature of the host rock, this review exercise has highlighted a number of common elements that are of importance to the various European waste management agencies. These include, among others, heavy load transportation technology, waste canister emplacement technology, retrievability, buffer construction, monitoring activity and lining and temporary sealing with specific types of cements.

In addition, a special focus has been put on developing disposal concepts with minimal environmental impact particularly in terms of the ratio of disposed volumes of waste versus total excavated volume of host rock. This reduces the amount of muck (broken host rock) that must be stored on surface and it also minimises the disturbance within the host rock horizon. Recently, most waste management agencies in Europe have shown a strong interest in horizontal disposal concepts although concepts for waste disposal in deep vertical boreholes are also being developed.

The research has led to the integrated project known as Esdred (Engineering Studies and Demonstration of Repository Designs), a joint research effort by major national radioactive waste management agencies (or subsidiaries of agencies) and by research organisations, representing nine European countries: Belgium, Finland, France, Germany, Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Esdred, part of the European Union's (EU's) 6th Euratom Framework Programme for Nuclear Research and Training (2002-2006), is a major step towards establishing a sound technical basis for demonstrating the safety of disposing of spent fuel and long-lived radioactive wastes in deep geological formations and to underpin the development of a common European view on the main issues related to the management and disposal of radioactive waste.

With a total budget of €18 million (of which €7.3 million is from the Framework Programme) the overall objective of the Esdred project, over a five-year period is to demonstrate, in compliance with requirements regarding operational and long-term safety, retrievability and monitoring, the technical feasibility at an industrial scale of activities such as:

- Buffer construction technologies for horizontal disposal concepts (Module 1).
- Waste canister transfer and emplacement technology for horizontal and vertical disposal concepts (Module 2).
- Heavy load emplacement technology for the horizontal disposal concepts (Module 3).
- Use of specific low pH cement and shotcrete techniques to build disposal vault sealing plugs and/or to reinforce underground structures and linings (Module 4).

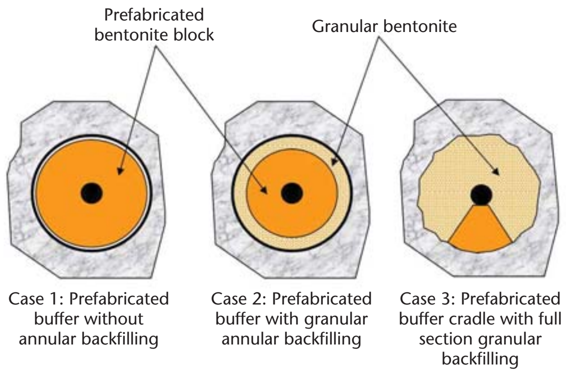
The ultimate objective of the above activities is the fabrication and working demonstration of full-scale prototypes whenever possible. An additional training and communication module, that cuts across all the technical modules has been specifically developed to ensure the consistent integration between the above modules and manage a special programme of training for engineers and the transfer of technologies. This is particularly intended for the new members states of the EU and will be proposed throughout the project, primarily in the form of secondment opportunities or seminars.

MODULE 1: BUFFER TECHNOLOGY

This component of the project, handled by Ondraf/Niras, the public authority charged with handling radwaste in Belgium, is to design and construct an engineered barrier or buffer for a horizontal disposal drift in three different scenarios.

When the safety analysis demonstrates the need for an engineered barrier to be placed between the waste canister or overpack and the disposal cell lining, three engineering and technological options can be considered:

Sketch of basic design of buffer construction (disposal cell diameters of 3-4m)



- The solid buffer is placed in the disposal cell and later the waste canister is emplaced within the buffer.
- A super-container type of waste canister (which includes part of the engineered barrier) is emplaced in a disposal cell and the annular space between the canister and the tunnel may be filled with granular buffer afterwards.
- The waste canister is emplaced on a solid buffer cradle and then granular buffer is used to fill the disposal cell.

These three cases of building a buffer barrier around a waste canister are shown in the sketch, above.

Various considerations may lead to the choice of one or another of these solutions, if proven feasible at an industrial scale consistent with various safety requirements such as maintaining an acceptable clearance in between disposal cell lining and the buffer.

The buffer construction is first carried out on surface and later it is fitted into the disposal cell but always in a non-nuclear environment which is therefore less demanding in terms of operational safety. In the example of Case 1 this involves:

- The feasibility of constructing large pieces of compacted bentonite rings.
- Large pieces of buffer being transported and fitted into the disposal cell.
- The later emplacement of the irradiating waste canister via a shielding cask.

The issue of retrievability also needs to be considered for each of the three. Case 1 appears to have an advantage.

The super-container (constructed in a surface facility), as in the example of Case 2, may provide partial biological and radiological protection, therefore allowing emplacement work to take place in a non-irradiating environment. This is therefore much less demanding in terms of operational safety, but still involves:

- Handling large and eventually very heavy cargoes.
- The possible addition of an annular buffer.

The initial waste emplacement followed by full section granular backfilling (Case 3) is suitable for operations involving small to medium sized waste canisters and other materials.

However, it involves working in a nuclear (irradiating) environment both for waste emplacement and for buffer backfilling, therefore more demanding in terms of operational safety.

The planned demonstrations and fabrication of prototypes include:

- Workshop fabrication of bentonite rings.
- Workshop testing of granular buffer installation techniques.
- *In situ* gas and water permeability testing of a compacted granular buffer at the Mont Terri underground laboratory.
- *In situ* testing of annular gap-filling technology at the Mol underground laboratory
- Non-intrusive monitoring techniques using wireless technology associated with the above demonstrations.

MODULE 2: CANISTER EMPLACEMENT

Module 2, led by DBE technology of Germany, consists of the design and construction of two sets of demonstrator prototype equipment including, among other things, a shielding cask, a transport vehicle, a pushing robot and docking facilities to be used for the remote controlled emplacement of irradiating waste canisters.

The next step after the buffer outfitting of the disposal cell is the irradiating waste canister emplacement. This therefore requires the use of a shielding cask. Without an engineered barrier, the emplacement operation in a horizontal vault or a vertical borehole would be very similar.

Even though the surface transportation of radioactive waste is now quite common, emplacement in an underground geological environment presents additional challenges such as:

- The retrievability issue.
- The docking and transfer operation for moving the waste canister from the shielding cask into the disposal cell.
- A shielding cask is required for transportation, however manoeuvring room is much more restricted underground.

The planned demonstrations and prototypes include:

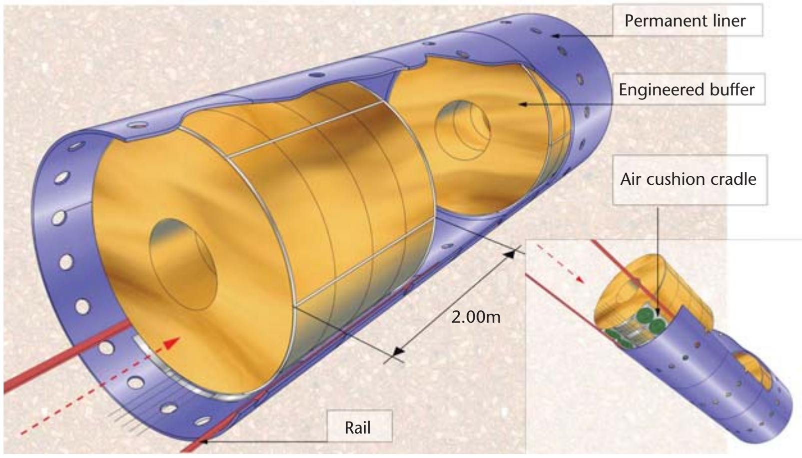
- Fabrication and workshop testing of two sets of mechanical components required for vertical and horizontal transportation and emplacement.
- *In situ* testing of the horizontal emplacement equipment in an underground facility to be determined later.
- Testing of the vertical emplacement equipment in a surface facility.

MODULE 3: HEAVY LOAD EMPLACEMENT

Sweden's SKB is leading this effort to design and construct various demonstrator prototypes for emplacement of heavy prefabricated buffers, waste canisters or super-containers in a repository with horizontal disposal cells or drifts.

Horizontal emplacement of either a super-container (including buffer material and the waste canister) or of a large piece of prefabricated bentonite buffer

Emplacement of a 15t set of prefabricated bentonite rings in a disposal cell equipped with a steel liner



ring is a necessary operation if we consider Cases 1 and 2 of Module 1.

In order to limit the friction that must be overcome when moving such heavy loads in a confined area, the option of using fluid (air or water) cushion technology is considered. This technology is widely used in civil engineering with compressed air blown in between two flat horizontal surfaces.

The particular challenge is to demonstrate that fluid cushion technology can be used between two cylindrical surfaces for moving heavy loads. Clearly, the cylindrical shape of the surfaces reduces the uplift force with respect to horizontal surfaces.

Using water, which is a heavier fluid than air, rather than air, increases the uplift force and therefore compensates somewhat for the loss due to the cylindrical feature of the surfaces. In all cases, the fluid type and flow rate must also be compatible with the underground environment.

The planned demonstrations and prototypes include:

- Prototype testing of air cushion technology for a spent fuel canister.
- *In situ* emplacement of a KBS-3H super-container (developed by SKB) in the Aspö underground laboratory.
- Emplacement of a full-scale mock-up and later real fabricated buffer in a suitable workshop.
- Emplacement of a full-scale mock-up of a spent fuel canister inside a steel liner.

MODULE 4: CELL PLUGS AND REINFORCEMENT

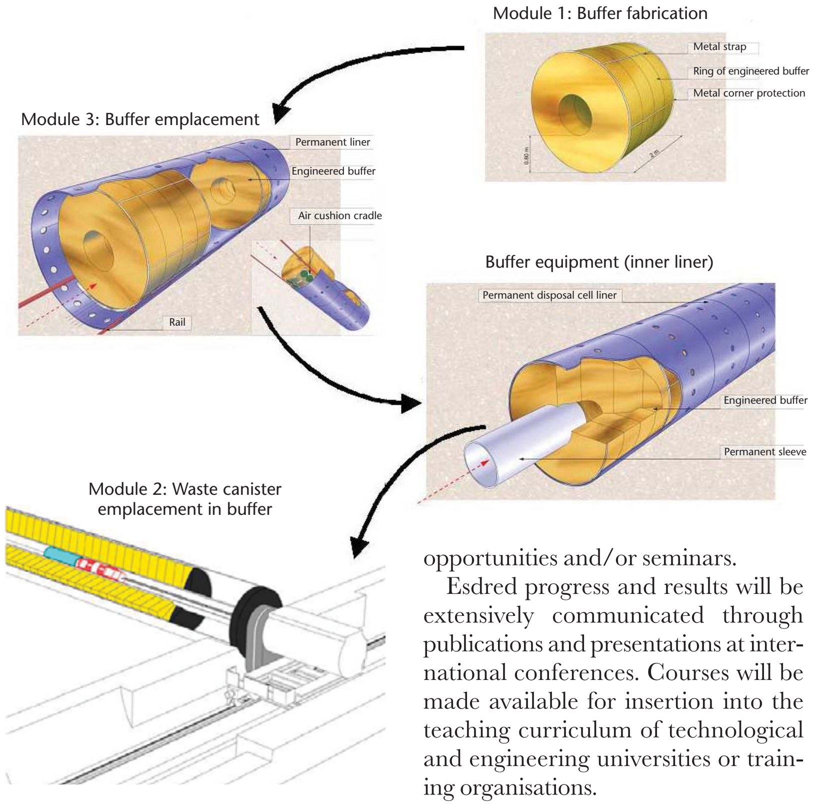
Spain's Enresa is leading this module to develop and validate specific 'low pH' cement and later demonstrate its application by constructing a sealing plug using shotcrete techniques.

Cementatious materials are widely used in underground civil engineering, but in the case of radioactive waste disposal, the geochemical phenomenology has to be considered in the long-term safety analysis. This includes, for instance, the possible interaction with the vitrified waste matrix or with the geological medium through a so-called plume effect.

In order to reduce these interactions, a 'low pH' (less basic) cement is being developed. Nevertheless this development must also include the placement of this cement at an industrial scale through the shotcrete technique.

Finally, its performance as a sealing material must be evaluated.

These two objectives will be completed with a full-scale test of a shotcrete sealing plug.



Example of links between Modules 1, 2 & 3

COORDINATION

The example above clearly illustrates the need for coordinated management aiming for continuous integration in order to maintain consistency between the various technological activities.

A package of several prefabricated buffer rings developed and manufactured in Module 1 must be placed in the disposal cell using the air/water-cushion technology developed in Module 3. Then, once the buffer rings are in place, the inner liner must be installed (Module 2) inside the prefabricated buffer assembly. Furthermore, the waste canister emplacement technology developed in Module 2 must be consistent with the prefabricated buffer assembly in terms of inside diameter, weight resistance and material compatibility.

TRAINING AND COMMUNICATION

Training, communication, integration and management is the responsibility of France's Andra. This organisation must ensure wide communication of results towards the engineering community, transfer of technology, notably for new member states and dissemination of information to all stakeholders.

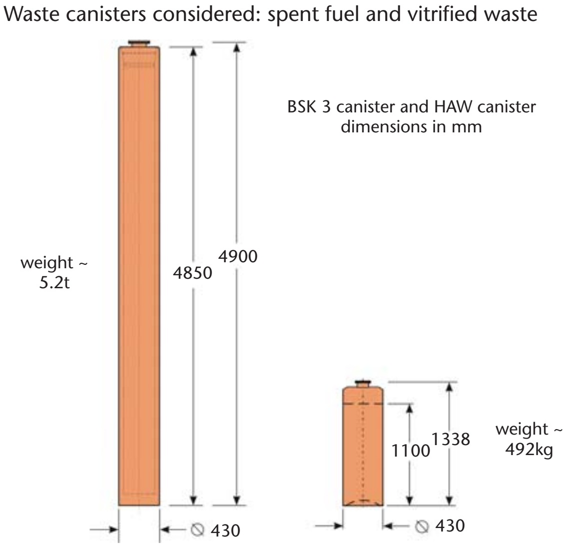
A special programme involving the training of engineers and the transfer of technologies, especially intended for the new member states of the EU, will be proposed throughout the project, primarily in the form of secondment opportunities and/or seminars.

Esdred progress and results will be extensively communicated through publications and presentations at international conferences. Courses will be made available for insertion into the teaching curriculum of technological and engineering universities or training organisations.

Radioactive waste management is also a societal issue and, as such, it concerns a wide range of stakeholders apart from the usual research and engineering community. These would include national and local political representatives, stakeholders' oversight committees, societies for the protection of the environment, such as NGOs and the public at large, notably if concerned by a siting process.

The Esdred project team is available to present and explain the objectives and issues of the project on request in such forums.

Waste canisters considered: spent fuel and vitrified waste



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