Geological disposal of high-level and long-lived radioactive waste

Context

In Belgium, radioactive waste predominantly emerges from electricity production in the nuclear power plants of Doel and Tihange. Currently, this waste is stored in various on-site storage facilities or in the storage facilities of Belgoprocess in Dessel. As a final solution for the management of high-level and long-lived radioactive waste, the possibility of disposal in low-permeability clay formations is explored. As early as 1974, SCK•CEN has launched a research programme to investigate whether the Boom Clay is suitable for hosting a radioactive waste repository.

The disposal concept developed by ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials, includes a central access infrastructure consisting of a minimum of two shafts with elevators for waste and staff, access galleries and disposal galleries (Figure 1). The underground disposal facility is subdivided into separate zones based on waste type.

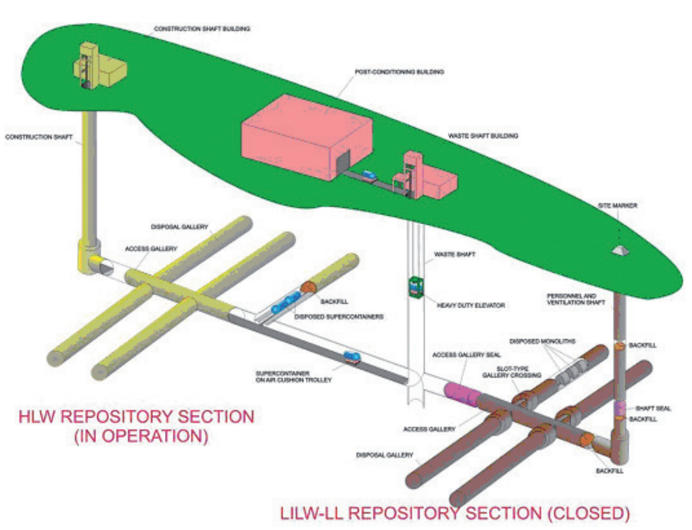


Figure 1: Schematic representation of a disposal facility in a low-permeable clay formation. (© ONDRAF/NIRAS)

In order to confine the radionuclides that are embedded in the high-level waste within the repository system for at least some thousands of years, the so-called supercontainer concept was developed (Figure 2). This concept aims at establishing and maintaining a chemical environment around the overpack that guarantees full containment (preventing contact of radionuclides with pore water) during at least many thousands of years. Indeed, the use of massive amounts of cement-based materials ensures highly alkaline conditions, which will considerably contribute to the longevity of the carbon steel overpack by minimising corrosion.

The concrete buffer will also provide radio protective shielding for the workforce during underground operations. A supercontainer can contain up to four spent fuel assemblies or two vitrified waste canisters. After placement of the supercontainers in the disposal galleries, the remaining void spaces will be backfilled with a cement-based material and the repository will be closed.

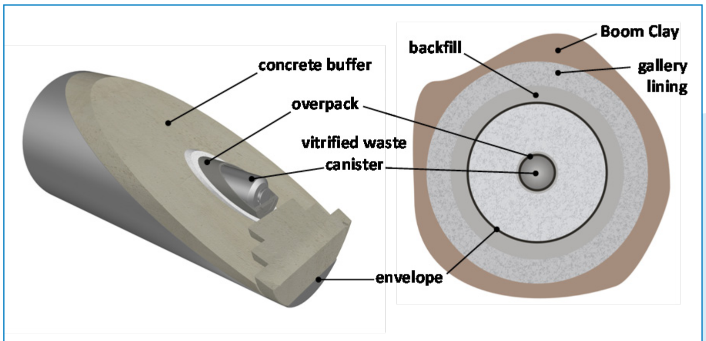


Figure 2: Schematic representation of the supercontainer design. (© ONDRAF/NIRAS)

The functioning of the disposal system can be explained by means of so-called safety functions:

- The first safety function is the isolation of the waste from humans and the biosphere, through placement of the waste in a geologically stable formation at a depth of at least several hundred meters.
- The second safety function is the full containment of the radionuclides within the overpack for several thousands of years. This initial phase is the so called thermal phase during which the temperature in the surrounding clay increases such that the potential effect on radionuclide migration becomes difficult to quantify.
- The third safety function is delay and attenuation of the radionuclide releases to the biosphere. This function has three components:
  - The very stable waste matrix (e.g. glass) makes that the embedded contaminants are released only very slowly.
  - In the low-permeable clay host formation, advection is negligible. Hence, contaminants are only transported by diffusion, which is a very slow process.
  - Moreover, various contaminants are highly insoluble and/or are absorbed by the clay or concrete minerals.

These very slow processes give the radionuclides the time to decay within the engineered and natural barriers, such that eventual releases to the biosphere are negligible.

Objectives

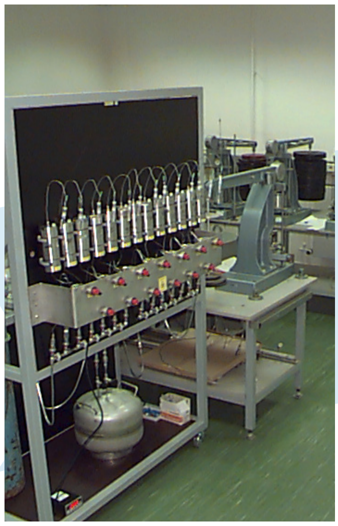
- Through laboratory and in situ experiments, develop understanding of the processes that govern radionuclide release from the waste forms and radionuclide migration through engineered and natural barriers and develop the feasibility of building the envisaged geological repository from technical perspective.
- Develop models that describe the thermal, hydraulic, chemical and mechanical evolution of the repository system in order to evaluate the long-term radiological consequences of a geological disposal system for high-level and long-lived radioactive waste.

Main activities

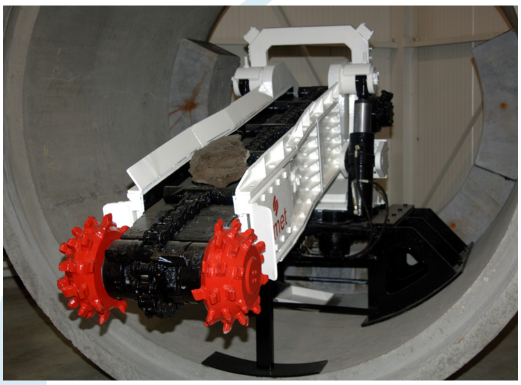
- Research the feasibility of excavation of gallery structures in the Boom Clay.
- Research the behaviour of engineered barriers in repository conditions and the transport behaviour of radionuclides in a clay formation.
- Perform safety evaluations of a radioactive waste repository system in a clay formation.

Vitrified waste canisters.

Laboratory set-up of the water uptake cell used for the study of the water uptake, swelling, and $NaNO_3$ leaching of non-radioactive Eurobitum samples.



Experimental set-ups used for the direct measurement of radionuclide migration parameters.



Part of the machine used for the excavation of the underground research laboratory HADES, 225 metres under the SCK•CEN site.

Inside view of the underground research laboratory HADES.

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