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STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

R&D on waste packages

Context

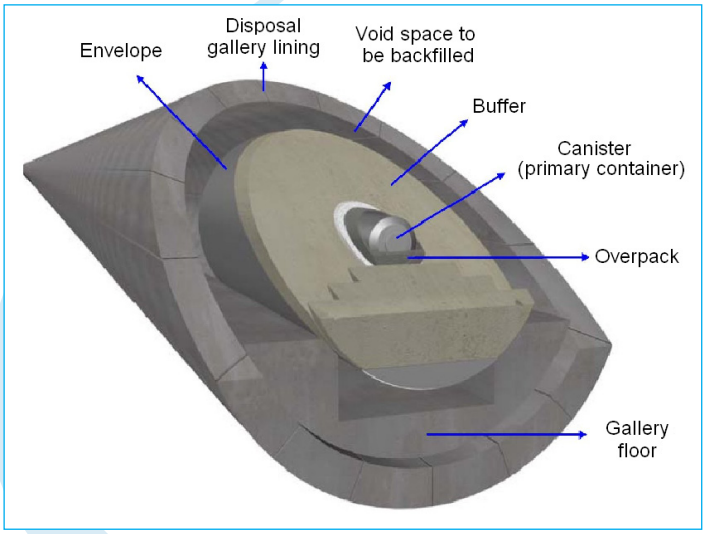
The current Belgian disposal design for medium- and high-level nuclear waste is based on deep geological disposal. The Boom Clay formation is being investigated as a candidate host rock. In the case of medium-level waste, the packages are placed in concrete monoliths in the disposal gallery. For vitrified high-level waste and spent fuel the Supercontainer design foresees emplacement of the waste in a carbon steel overpack surrounded by an Ordinary Portland Cement buffer.

The Research Unit R&D Waste Packages investigates the long-term behaviour of both the waste forms and the overpack. Three main research activities can be distinguished in this unit, i.e. the study of:

- High-level vitrified waste and spent fuel.
- The compatibility between Eurobitum bituminized medium-level waste and the Boom Clay.
- The corrosion of the carbon steel overpack.

Studies on high-level vitrified waste and spent fuel

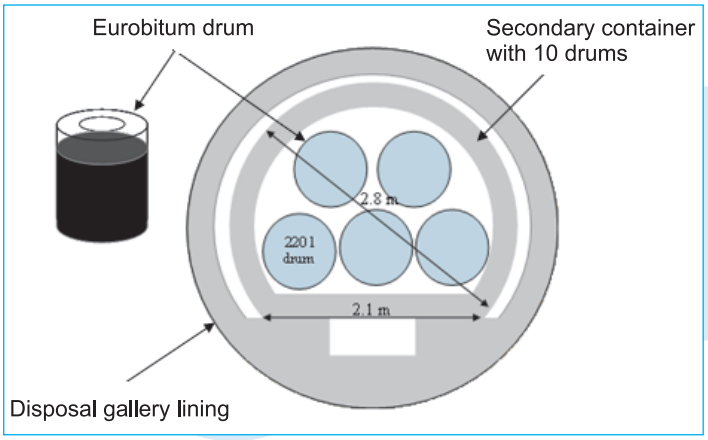
Vitrified waste contains in its glass matrix most radionuclides resulting from the reprocessing of spent fuel. In unreprocessed spent fuel, most radionuclides are dissolved in the uranium oxide matrix of the fuel. Although the glass and uranium oxide are relatively inert materials, they tend to undergo slow alterations when they are in contact with ground water, as expected under geological disposal conditions. This will cause the slow release of the incorporated radionuclides. The retarded release is one of the safety functions on which geological disposal relies.



Belgian Supercontainer concept for disposal of high-level nuclear waste. (© ONDRAF/NIRAS)

Study of the compatibility between Eurobitum bituminized medium-level waste and the Boom Clay

Due to the large amounts of $NaNO_3$, which is a hygroscopic and soluble salt, in Eurobitum; the emplacement of the bituminized waste will induce several processes that could have a significant effect on the barrier function of the clay. Owing to the importance of the clay host formation in the overall repository safety, the compatibility of Eurobitum with the Boom Clay is investigated in the Belgian research programme on Eurobitum. Both a possible geo-mechanical and geo-chemical disturbance of the clay are investigated.



Belgian concept for disposal of Eurobitum medium-level nuclear waste. (© ONDRAF/NIRAS)

Study of the corrosion of the carbon steel overpack

Low alloy steel is being considered as a candidate overpack material for the Supercontainer design. In the highly alkaline environment within the Supercontainer, the carbon steel overpack will be protected by a passive oxide film, which is believed to result in very low uniform corrosion rates. The RD&D corrosion programme investigates the long-term corrosion behaviour of the carbon steel overpack to predict its lifetime.

Objectives

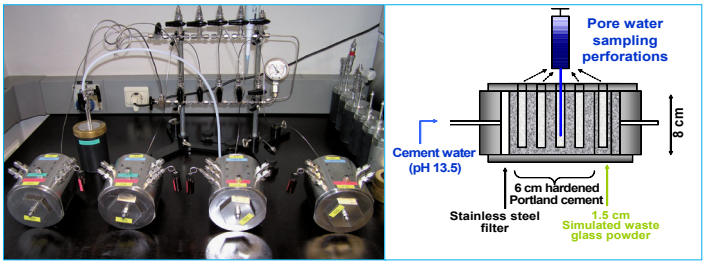
The overall objective of the research performed by the unit R&D Waste Packages is to provide data for the safety assessment of medium- and high-level nuclear waste disposal. Therefore, research is performed on:

- Alteration rates and mechanisms of high-level vitrified waste and spent fuel under conditions relevant for the Supercontainer design.
- The geo-mechanical and geo-chemical compatibility between Eurobitum bituminized medium-level waste and the Boom Clay.
- The lifetime of high-level waste overpacks, i.e the study of the active-passive corrosion behaviour of the carbon steel overpack under conditions relevant for the Supercontainer design.

Main activities

Studies on high-level vitrified waste and spent fuel

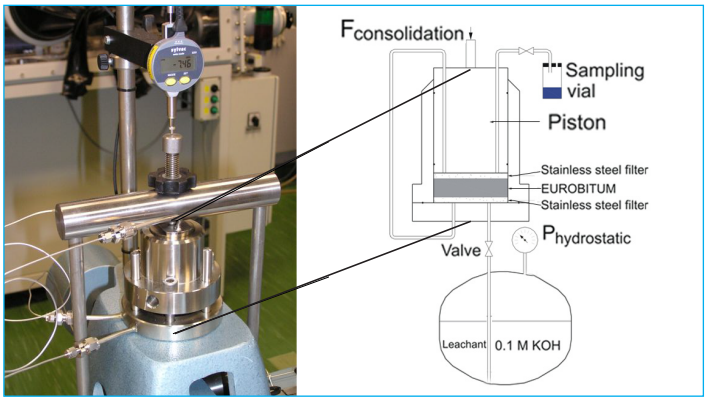
The research programme on high-level vitrified waste and spent fuel aims at investigating the slow release of radionuclides from both waste forms. The retarded release is one of the safety functions on which geological disposal relies. The rate of this release is an important parameter in the safety calculations. To determine this release rate, simulated and real waste forms are tested in laboratory conditions that simulate the disposal environment. Waste samples are exposed to cement water, with or without other materials that will be part of the disposal gallery (cement, steel and their degradation products).
The alteration of the waste form is monitored by measuring the increasing concentrations of waste components in the cement water and on the surface of other materials, and by analysis of the waste forms after the exposure. The results are interpreted by means of kinetical and geochemical models. The resulting system understanding allows a robust estimation of the life time of the waste forms under disposal conditions.



Laboratory set-up and schematic cross-section of percolation cells for the determination of glass dissolution rates under conditions relevant for the Supercontainer design.

Study of the compatibility between Eurobitum bituminized medium-level waste and the Boom Clay

The research programme on Eurobitum aims at investigating a possible geo-mechanical and geo-chemical disturbance of the clay. The geo-mechanical perturbation of the clay is caused by swelling of the waste and by the increase of the pressure in and around the waste, which is investigated in water uptake tests with non-radioactive and radioactive Eurobitum samples. Meanwhile a hydro-chemical-mechanical constitutive law for Eurobitum is being developed at the International Centre for Numerical Methods and Engineering (UPC-Polytechnical University of Cataluña, Spain) to study the hydro-chemical-mechanical interaction between Eurobitum and Boom Clay. The geo-chemical perturbation of the clay is caused mainly by the release of large amounts of $NaNO_3$ from Eurobitum and is investigated in interaction tests with Boom Clay and nitrate. The extent and rate of the swelling, pressure increase and $NaNO_3$ leaching will be affected by the continuous evolution of the rheological properties of the bitumen in the bituminised waste, the so-called ageing, resulting in a harder bitumen. Recently, a procedure has been developed to characterize the ageing degree of (radioactive) Eurobitum by means of Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR).



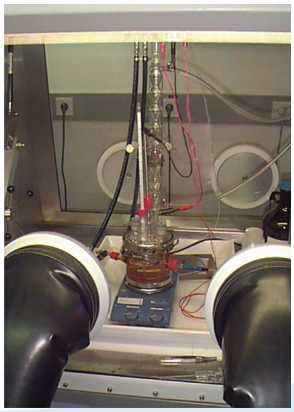
Laboratory set-up and schematic cross-section of the water uptake cell used for the study of the water uptake, swelling, and $NaNO_3$ leaching of non-radioactive Eurobitum samples.

Study of the corrosion of the carbon steel overpack

The RD&D corrosion programme investigates the long-term corrosion behaviour of the carbon steel overpack. The prediction of the lifetime of the overpack is based on:

- Literature survey: a vast amount of uniform corrosion rate data is available from industrial applications (e.g. building and construction usage).
- Dedicated experimental programmes to study the influence of several parameters on the uniform corrosion rate, such as e.g. temperature, gamma irradiation, concentration of aggressive species (chloride, sulphide, thiosulphate).
- Modelling calculations to better describe the evolution of the environmental conditions the overpack will be exposed to during the long time scales involved in geological disposal (temperature, pH, saturation degree, potential, pore water chemistry).

Because carbon steel exposed to concrete can undergo depassivation due to e.g. ingress of aggressive species, leading to localised corrosion attack (pitting corrosion, crevice corrosion, stress corrosion cracking), an experimental programme has been initiated to study the stress corrosion cracking (SCC) behaviour of the carbon steel overpack under conditions relevant for the Supercontainer. The Slow Strain Rate Testing (SSRT) technique is used to provide a first screening of the SCC susceptibility of plain carbon steel.



Electrochemical tests to study the active-passive corrosion behaviour of the carbon steel overpack under conditions relevant for the Supercontainer design.

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