

## WASTE AND DISPOSAL: DEMONSTRATION

### Background

Within the Belgian R&D programme on radioactive waste disposal, emphasis has gradually shifted from the study of basic phenomena to the investigation of complex and interacting processes. In line with this development, integrated tests and large-scale demonstration experiments have become increasingly important. A core group within the Department Waste and Disposal contributes to the developing of concepts and demonstration experiments in the HADES Underground Research Facility (URF). In particular, this group provides support to the Economic Interest Grouping (EIG) EURIDICE (European Underground Research Infrastructure for the DIposal of waste in a Clay Environment) in various fields of expertise like geomechanics and monitoring.

The Economic Interest Grouping EURIDICE was set up in 1995 by SCK•CEN and ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials. The EIG EURIDICE is in charge of the management of the HADES URF. Since 1995, the activities focus on the PRACLAY (PREliminary concept in CLAY) programme. The main objectives of the PRACLAY project are to demonstrate the technical feasibility of HLW disposal in a clay formation and to contribute to the assessment of the performance of the disposal system.

The PRACLAY demonstration project is an important milestone in the Belgian repository development programme. The demonstration experiment is based on two pillars:

- ▣ demonstrating the technical feasibility of the repository, taking into account the real and practical nature of the operations;
- ▣ contributing to a better understanding of the processes involved in the disposal system and the validation of mathematical models.

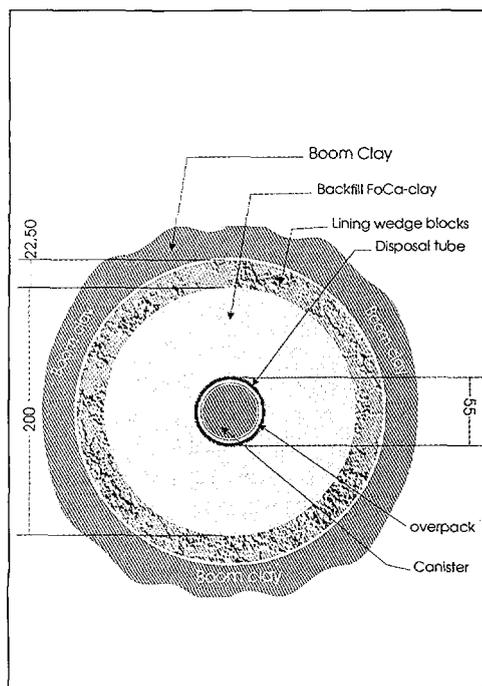
In the current Belgian disposal concept, a concrete-lined gallery contains a central stainless steel access tube intended to receive the vitrified HLW drums in their individual stainless steel overpack. Bentonite-based backfill blocks fill the gap between the central 0.5-m diameter tube and the 2-m inner diameter lining. In addition to activities planned in the HADES URF, a surface mock-up, OPHELIE (On surface Preliminary Heating simulation Experimenting Later Instruments and Equipments) has been constructed. The mock-up simulates a disposal gallery and will be used for preparing and complementing the underground work. The OPHELIE mock-up is 5 m long and has a cross-section similar to that of the disposal gallery as far as central tube and backfill are concerned. A steel liner keeps the backfill under pressure when the latter starts to swell due to water uptake. The mock-up was operated for 3 years at thermal conditions above 100 °C.

### Scientific staff

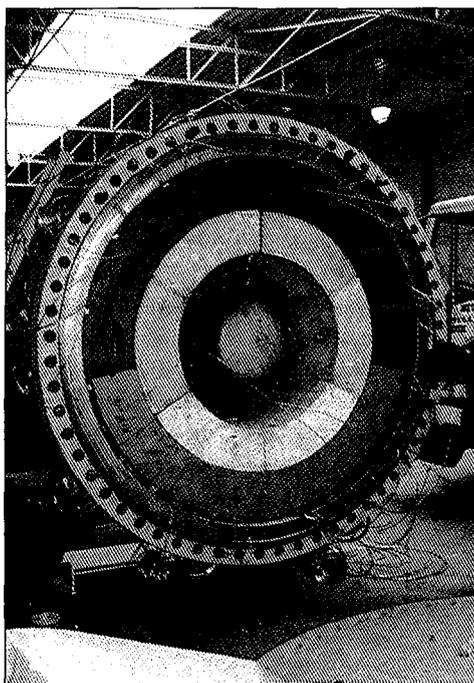
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Current Belgian disposal concept



Surface mock-up OPHELIE

## Objectives

- ❖ to contribute to the design, installation and operation of a surface mock-up, simulating at full scale (diameter) the Belgian reference concept;
- ❖ to confirm and improve our knowledge of the reference design;
- ❖ to design and build the crossing between main and disposal galleries;
- ❖ to demonstrate the construction and operation of a dummy disposal gallery for HLW;
- ❖ to increase our understanding of water flow and mass transport in dense clay-based materials and their mechanical behaviour under a temperature gradient;
- ❖ to valorise our expertise and stimulate co-operation at international level.

## Programme

The PRACLAY demonstration experiment will be installed in a dedicated gallery in the HADES facility. This gallery with a total length of 30 m will be constructed in an extension of the present URF. In a first step, the excavation in 2002 of the gallery connecting the second shaft with the existing facility, will provide a unique opportunity to monitor the evolution of Hydro-Mechanical (HM) disturbances of the Boom Clay formation in order to validate the current models on the HM behaviour of Boom Clay.

The EIG EURIDICE is directly involved in the EC (European Commission) FEBEX-II (Full scale Engineered Barrier Experiment) and CLIPEX (CLay Instrumentation Programme for the EXtension of the URL) projects.

- ❖ The FEBEX-II project is a continuation of the FEBEX project, initiated by ENRESA to demonstrate the Spanish design for spent fuel disposal but operated in Switzerland in a granite formation at the Grimsel Test Site. Although referring to the Spanish context for spent fuel and the granite as host rock option, EIG EURIDICE considers this participation useful to share through this European partnership experience and methods on the dismantling operations of such an *in situ* test, having many similarities with the PRACLAY experiment.
- ❖ The CLIPEX project is a mine-by test, developed in parallel with the extension of the URF planned for begin 2002. The instrumentation already installed in the clay host in 1999, will record the HM parameters ahead of the tunnel face with a particularly high reliability, taking advantage of

an optimal restoration of the ground conditions around the sensors for more than 2 years. The instrumentation array will be extended to engineered structures to be built.

In December 2000, ONDRAF/NIRAS decided to review the reference design for the disposal of vitrified and heat generating high level waste due to open questions resulting from preliminary studies regarding the PRACLAY experiment, from intermediate results of the OPHELIE mock-up and from studies carried out during the elaboration of by ONDRAF/NIRAS of the Safety and Feasibility Interim Report (SAFIR 2). As the PRACLAY project is meant to be the demonstration of the feasibility of this reference design, it is obvious that this two-year review period will affect the planning of the PRACLAY experiment. However some parts that are largely independent of the design, are continued.

## Achievements

The Waste and Disposal Department contributed to the operation of the OPHELIE mock-up and the preparation of its dismantling, which is scheduled for the second semester of 2002.

Based on the design of the mid-nineties, the EIG EURIDICE constructed OPHELIE to confirm several choices initially made for the PRACLAY *in situ* experiment such as monitoring devices, backfill material, disposal tube and to test the feasibility of the installation procedures of the backfill blocks and measuring sensors. The mock-up, operated since December 1997, should allow to perform a basic investigation of the thermo-hydro-mechanical behaviour of the clay-based backfill material.

The success of the dismantling operations is therefore a prerequisite to allow a detailed study of Thermo-Hydro-Mechanical (THM) processes taking place. In particular, the dismantling of the mock-up will provide a unique "hands-on" experience of the engineered barrier, by visualising the different materials after hydration and heating during several years. As the barrier becomes accessible, the dismantling operation will provide an excellent opportunity to investigate the phenomena that may influence the performance of the different mock-up components. The measurements but also some observations during the experimental phase already allowed to point out specific features, like the high apparent thermal conductivity of the backfill material, the salt concentration within the backfill or the pitting corrosion detected on stainless steel tubing and possibly explaining the failure of several sensors.

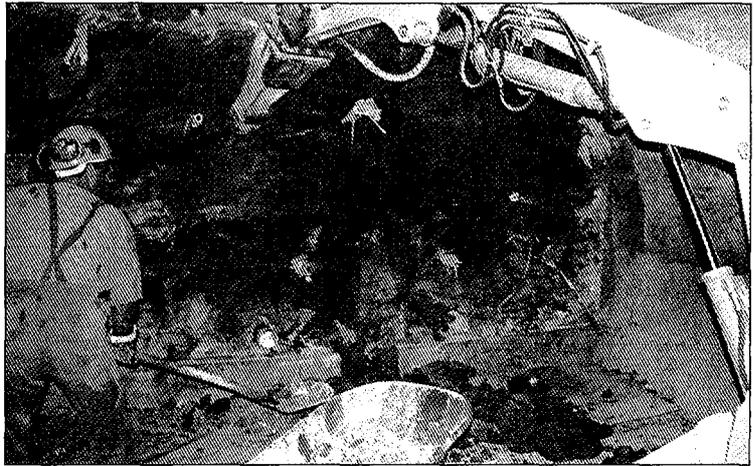
The construction of the connecting gallery is an experiment by itself as it is the first time that an industrial excavation technique will be used. The construction of this gallery will gather essential information regarding the excavation technique but also the understanding of the hydro-mechanical response of the clay massif during and after the excavation. Presently, the starting chamber required for mounting the tunnel machine is ready. The connecting gallery will be excavated early 2002.

For the construction of the connecting gallery, a tunnelling machine composed of a 2.3 m long shield, a road-header for the rock excavation and a bird-wing erector system for the lining installation was designed. The shield is equipped with a cutting head to ensure a smooth excavated profile. The wedge block system consisting in an expanded lining system is selected to reduce the plastic zone created by the tunnelling process. A fast advancing rate of about 2 meters a day and a minimal overbreak are required. A quick installation of the lining will minimise radial movement of the clay wall. The full instrumented tunnelling machine (forces exerted by the hydraulic jacks, convergence of the wall, etc) will allow a very good control of the excavation parameters.

Recent simulations of the excavation process supported the definition of the instrumentation programme. The mine-by test will in turn allow to test the capability of current models to reproduce the coupled HM behaviour of deep clays and to validate and/or refine these capabilities.

The following interesting results are already available:

- ☒ we recorded, for the first time from the HADES URF at a depth of 225 m, the expected undisturbed pore water pressure of 2.2 MPa, indicating a hydraulical disturbance limited to about 30 m behind the front of the drift;
- ☒ during the construction of the second shaft, we observed a water pressure drop about 0.2 MPa at a distance of about 60 m from the shaft. Simple poroplastic models predicting a maximum extent of 25 m distance for a similar disturbance under full deconfinement cannot explain these observations. This confirms that skeleton viscosity and fracturing in the near-field have to be taken into account;
- ☒ we observed a good agreement between preliminary results of simulations, run by the different modelling teams involved in the project;



*Excavation of the starting chamber*

- ☒ using the instrumentation recently installed at the bottom of the second shaft, we recorded the response of the clay host rock to the construction of the starting chamber taking place in September of this year.

In complement to the investigations initiated last year for the study of the fracturation observed around the second shaft, a new EC project (SEFLFRAC) on the self-healing behaviour of fractures, proposed by the EIG EURIDICE, was selected in the frame of the Fifth Framework programme of the European Commission on nuclear fission safety. Numerous geological observations during the digging of the starting chamber provide a new set of data to be analysed in more detail together with new information collected at the field (core drilling, micro-sonic measurements, etc).

In the frame of the IAEA Network of Centres of Excellence, SCK•CEN as a member of the EIG EURIDICE, has proposed to make the HADES URF available for international training and demonstration activities with the following objectives:

- ☒ to demonstrate waste disposal technologies;
- ☒ to contribute to the resolution of outstanding key scientific and technical issues;
- ☒ to support training, knowledge and technology transfer;
- ☒ to promote public confidence in geological disposal.

This programme forms part of a broader action to involve international partners for research and demonstration projects in connection with the URF. The initiative of IAEA provides an excellent opportunity to promote international co-operation and to share experience and know-how.

SCK•CEN continues its partnership within the Mont Terri project (Switzerland) and is involved for consultancy in the frame of the experimental programme to be developed at the URL project of ANDRA at Bure, France. The support programme of the Belgian Ministry of Economic affairs in the enhancement of nuclear safety in East and Central European countries allows us to maintain and develop co-operation and training activities. Finally, SCK•CEN is also involved in the Cluster Repository Project (CROP), an international EC-funded thematic network aimed at comparing and assessing results from investigations of engineered barriers in URL's.

## Perspectives

The gallery connecting the second access shaft to the HADES RUF with the existing underground facility will be completed in 2002. Subsequently, the ventilation system will be adapted (2003). The dismantling of the mock-up is planned for September 2002.

The instrumentation of the host rock in the frame of the PRACLAY experiment is scheduled for 2005. The excavation of the PRACLAY drift will only start after a stabilisation period estimated to last for at least 6 months. The PRACLAY experiment is therefore expected to be operational by the end of 2007. After a five year heating phase, a one year cooling period (2013) is required prior to dismantling.

The EC SELFRAC project has a duration of three years. The main objective of this research project is to understand and quantify the increase of the permeability related to crack proliferation around excavation in clays and the self-healing processes that could in turn reduce the permeability with time. Constitutive models will be developed or adapted to predict the occurrence and the intensity of these processes.

A doctoral thesis studying the influence of radiation and heat on the performance of optical fibres was completed in 2001. In continuation of this work, we are studying practical applications (e.g. dose sensor) in view of potential spin-offs in the development of optical sensor for the monitoring of in situ tests or even repositories.

A first broadening of our monitoring research will take place through two EC projects:

- the SOMOS (Safety and Operational Monitoring of repositories with fibre Optic sensing Systems) project, co-ordinated by SCK•CEN on the development and testing of fibre optic sensors for monitoring temperature, pressure and gasses;

- a thematic network focused on the development of strategies concerning monitoring, co-ordinated by NIREX, the Waste Agency in UK.

In the frame of valorisation and quality assurance, we are planning to develop next year new activities related to data and knowledge management. For more than 15 years, the department Waste and Disposal maintains databases gathering the measurements of all sensors installed in the HADES URF but also from our piezometric network covering groundwater levels in north-east Belgium.

According to the time frame (decades) for the research on waste disposal, knowledge must be preserved during at least the operational period of a repository.

A dedicated data and knowledge management system able to follow the fast evolution in information technology is therefore necessary. It is our aim in the coming year to develop a larger data management system that would incorporate besides the existing databases, the scientific reports produced by the department including all input information that makes the production of these reports possible. The latter would e.g. include the Data Collection Forms (DCF) compiling the parameters used in performance assessment (PA) studies, input and output files of codes, results of measurements from both surface and underground laboratory experiments.

In 2002, SCK•CEN will contribute actively to the IAEA's Network of Centres of Excellence for Training and Demonstration of Waste Disposal Technologies in Underground Research Facilities.

This network was established in October 2001 and its focus is on the use of underground research facilities to achieve progress in repository development. The HADES URF has been made available to the network of URF's for conducting in-situ R&D work and demonstration tests in HADES under the aegis of the IAEA. Project partners with highly developed R&D programs on radioactive waste disposal can take advantage of synergies in research. Member states with less advanced repository development programmes can benefit from the network through active participation in experimental work in HADES or through dedicated programmes for promoting the transfer and preservation of knowledge and technologies. The connection with the future European Research Area (ERA) to be developed by the EC within the sixth framework programme will be looked for.

-	Tractebel (Brussels, Belgium)	P. Borgermans, B. Brichard, F. Berghmans, M. Decréton, "Dosimetry with optical fibres: results for pure silica, phosphorous and erbium doped samples", SPIE Procs, Vol. 4204, pp. 151-160, International Conference on Fibre Optic Sensor Technology II, Boston, USA, Nov. 06-08, 2000.
ANDRA	Agence National pour la gestion des Déchets Radioactifs (Châtenay-Malabry, France)	M. Demarche, F. Bernier "The PRACLAY Project: Demonstration of the Feasibility of the Belgian Reference Concept for HLW, Proc. ICEM'01, The 8th International conference on Environmental Management, Bruges, Sept.30 – Oct.4 2001.
CEA	Commissariat à l'Energie Atomique (Saclay, France)	M. Demarche, F. Bernier "EURIDICE EIG and Extension of the URL, inc. the CLIPEX Project", 2nd CLUSTER URL's Seminar, Book of abstracts, European Commission.
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (Madrid, Spain)	B. Neerdael, "The use of scientific and technical results from underground research laboratory investigations for the geological disposal of radioactive waste", IAEA-TEC-DOC-1243, September 2001.
CSIC	Consejo Superior de Investigaciones Científicas (Madrid, Spain)	A. Sneyers, G. Volckaert, B. Neerdael, "The Belgian Research, development and demonstration program on the geological disposal of long-lived and high-level radioactive waste and spent fuel in a clay formation: status and trends", WM'01, Proc. Waste Management 2001 Symposium, Tucson (AZ, USA), Feb 25 - Mar 1, 2001.
ENRESA	Empresa Nacional de Residuos Radiactivos, S.A. (Madrid, Spain)	J. Verstricht, M. Demarche, C. Gatabin "Development of a Backfill Material within the Belgian Concept for Geological Disposal of High-level Radioactive Waste: An Example of Successful International Co-operation", WM'01, Proc. Waste Management 2001 Symposium, Tucson (AZ, USA), Feb 25 – Mar 1, 2001.
KULeuven	Katholieke Universiteit Leuven (Leuven, Belgium)	J. Verstricht, D. De Bruyn, M. Demarche "Extension of the Underground Research Facility for Real-Scale Demonstration", WM'01, Proc. Waste Management 2001 Symposium, Tucson (AZ, USA), Feb 25 – Mar 1, 2001.
NRG	Nuclear Research Group (Petten, the Netherlands)	J. Verstricht, D. De Bruyn, B. Dereeper "Mock-up Simulation for the Demonstration of the Belgian High-Level Radioactive Waste Disposal Concept", Proc. ICEM'01, The 8th International conference on Environmental Management, Bruges, Sept 30 – Oct 4, 2001.
SKB	Svensk Kärnbränslehantering AB (Stockholm, Sweden)	
ULB	Université Libre de Bruxelles (Brussels, Belgium)	
UPC	Universitat Politècnica de Catalunya (Barcelona, Spain)	
EC	European Commission (Brussels, Belgium)	
IAEA	International Atomic Energy Agency (Vienna, Austria)	
MEZ	Ministry of Economic Affairs (Brussels, Belgium)	
ONDRAF/NIRAS	Belgian Agency of Radioactive Waste and Enriched Fissile Materials (Brussels, Belgium)	

## Publications

J. Bel, F. Bernier "Temperature Criterion Related to Clay Based Backfill Materials in the Framework of a Geological Repository of Heat Producing Radioactive Waste (HLW), Proc. ICEM'01, The 8th International conference on Environmental Management, Bruges, Sept.30 – Oct.4 2001.

F. Bernier "Fracturing and Self-Healing in the Boom Clay; Evidences and Further Studies" , Self-Healing Topical Session Proceedings, 11th Clay Club meeting, OCDE.

## Reports

F. Bernier, D. De Bruyn, M. Demarche, J. Verstricht (2001), "CLIPEX: Fourth annual report January 2000 – December 2000", EC contract FI4W-CT96-0028, Ref. 01-152, EIG EURIDICE.

D. De Bruyn (2001), "Rapport envers l'ONDRAF des activités du GIE PRACLAY/EURIDICE pour la période 1998-2000", Ref-01-228, EIG EURIDICE.

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B. Dereeper, J. Verstricht, D. De Bruyn, K. Moerkens, P. De Cannière, B. Kurtsen., R. Gens (2001) *PRACLAY Project – Mock-up Ophélie: Dismantling vers. (0)*, ESV EURIDICE GIE report 01-230, Mol, April 2001.

### **Presentations**

A. Sneyers, B. Neerdael, "Nuclear Waste Management", Workshop and Exhibition, EC Information day 6<sup>th</sup> Framework Programme 2002-2006, Brussels, 6 December, 2001.