THE FRENCH UNDERGROUND RESEARCH LABORATORY PROGRAM, CONTRIBUTION TO THE FEASIBILITY AND SAFETY STUDIES OF GEOLOGICAL DISPOSAL

J.M. HOORELBEKE, J.M. NIEZBORALA, K. BEN SLIMANE
ANDRA,
Parc de la croix blanche,
Châtenay Malabry CEDEX, France

Abstract

The paper presents the content of the research program to be performed during the construction and the operation of the National Agency for Radioactive Waste Management’s (ANDRA) underground laboratory, located in the East of France. The general architecture of the program is presented. Emphasis is put on an iterative process, the purpose of which is mainly to:

- Prepare site behavior models before starting each phase of the field work (bore hole drilling, shaft sinking, construction of underground galleries, specific experiments),
- Test and check each model through actual observations and measurements,
- Adjust the models to take into account the results of the former phase and predict the results expected during the following one. All these models, after validation, will be exploited during the assessment of the safety related performance of the components of the potential repository as well as the whole facility,
- Obtain necessary data related to the feasibility study of the disposal facility (mechanical design, thermal design, etc.,) and its safety assessment.

The relationship between the experimental program, the conceptual design program and the safety evaluation program is explained in order to reach the project objectives which is the final document set to be provided to French Authorities in 2006 according to the French Law of December 1991.

1. INTRODUCTION

After having gone over the status of the high level waste disposal program in France (§2.1), and having briefly described the research project, its objectives related schedule (§2.2), the more detailed contents of the field program are described (§3) and the relationships between this program, the conceptual design program and the safety evaluation program are explained (§4).

2. STATUS OF HIGH LEVEL, LONG LIVED WASTE (HLW) PROGRAM

2.1. Status of HLW program

The French Law of 1991 on research concerning the management of high level, long lived radioactive waste includes a program with 3 axes: partitioning and transmutation, long term surface storage and disposal in deep geological formations. ANDRA is in charge of this last research direction.

The Law sets a fifteen-year period for research ending in 2006, after which the Government will submit in 2006 an overall report (evaluating the results of the research for all three directions) to Parliament. Depending on the results, this report would be accompanied by a draft law, which could eventually authorize the process of repository installation.
Within this framework ANDRA is expected to assess by the year 2005 the feasibility of the design and safety demonstration of disposal in deep geological formations; this goal implies to provide an answer to the major scientific technical issues relating this feasibility. A range of pertinent disposal concepts will be proposed in 2005, as well as related hypotheses of waste production and acceptance criteria.

This work requires that appropriate geological formations be chosen field experiments in geological formations undertaken (to assess the true geological characteristics of a site to select and calibrate the models used in the design of disposal concepts and in the safety analysis).

ANDRA therefore filed applications for approval of implementation of 3 underground laboratories on three potential sites in 1996. These applications were submitted to site specific public inquiries and local votes in 1997. Taking into account the results of these inquiries and scientific evaluations, the Government decided in December 1998 that ANDRA should:

- Continue with the construction of an underground laboratory at the proposed site in the East of France\(^a\) (Callovo-Oxfordian clay site) and to use it for research;
- Carry out a search for a new granitic site.

2.2. Objectives of the field research program

Obviously the geomechanical research program is key in a clayey rock, with relatively low mechanical strength:

- Results of the research can be used to confirm the feasibility of the large disposal cavities used to dispose of long life waste.
- A good understanding of the mechanical behavior of clay over long periods of time is needed to analyze feasibility of rock support with regard in particular to reversibility: once waste packages are in place, the reversibility issue is linked to that of rock support life since this life must be prolonged to increase the period over which reversibility is possible.

Mechanical characteristics of the media, as is the case for other characteristics, vary according to location of measurement, since the geological media is stratified and includes heterogeneity.

This means that geological modeling is needed for the research to progress correctly. This modeling is phased. The first phase has been achieved thanks to reconnaissance work at ground level. This work has helped define laboratory architecture, length and direction of galleries. Using the laboratory itself, the next phase from 1999 to 2003 will aim at obtaining consistent 3D geological modeling, through geophysical measurements and in situ observations.

Concerning confinement capacity of the host rock, laws that describe the movement of the water and solute contained in the clay itself and the chemical composition of this water have been identified as the basic phenomena both for disposal design and for safety evaluation, in particular as regards their effects on radionuclide mass transport and chemical retention. Concerning reversibility appraisal, these parameters also set:

- The rehydration time (i.e. the time taken by water contained by the geological media to occupy space left empty in the underground cavities),
- The corrosion rates of the various metallic structures,
- Concrete degradation.

\(^a\) In the East, due to its location in the Parisian sedimentary basin, the argilite clay layer is homogeneous over a very large horizontal extension. The thickness of this layer is around 130 meters and is located between - 425 m and - 555m. The main level of the laboratory is located in the middle of this layer at -490m.
Modeling of these phenomena started by characterizing ground level samples. This is limited by:

- The low permeability of the clay: it is an important factor for disposal design but it makes extraction of water contained in rock samples difficult,
- The difficulty in sampling from ground level, through boreholes that perturb the samples.

These difficulties make measurements inaccurate. One of the underground research program's goals is therefore to increase measurement accuracy, though various measurements using samples taken from the laboratory.

To model past and future water circulation, the program also includes porewater pressure measurements and isotopic dating. These measurements will start in 2002 and continue over a few years.

Lastly, the natural confinement capacity of the media must not be overly disturbed by construction of the disposal facility and this issue must be checked. This means that some experiments are planned in the Underground Research Laboratory to verify the minimal degree of disturbance induced by the disposal (such as the effects of the heat radiated by high level long lived waste).

2.3. Research laboratory schedule

Assuming the official authorization to start construction of the underground laboratory in the East of France in July 1999, the major milestones of the construction are the following (start dates):

- First on site borehole drilling 9/1999
- Access shaft sinking 9/2000
- Vertical mine by test from a niche (@-445m, intermediate level) 3/2002
- First experimental gallery mining (main level) 8/2002

3. CONTENTS OF THE FIELD RESEARCH PROGRAM

3.1. Geological survey and modeling

The 3D layout of the Underground Research Laboratory (URL), including 2 inclined reconnaissance drifts and a niche at the upper level, provide access to a range of geological situations, consistent with the variability of the argillite layer: Major phenomena with respect to repository design and safety analysis will be characterized in these various geological situations.

Geological modeling will be based on data obtained by geological surveying of the shaft and galleries. This will be used throughout the project for supporting:

- Phenomena modeling such as hydrogeology,
- Sampling plans of the experiments detailed below (identifying valid spatial distributions of the experiment, specifying frequencies and locations),
- Design potential repository architectures.

This geological surveying is undertaken throughout the laboratory.

3.2. Modeling the isolation performance of the clay formation

The characterization of the confinement capacity of the host formation is based on different types of experiments:

---

b This date remains a target date and remains to be confirmed
• The permeability and the porewater pressure of the host formation are measured in various geological situations within the clayey layer; the data are then used to confirm the values of convective transport parameters in the host formation (it is also used to appreciate permeability of the formation to gas).

• Through porewater sampling, in the underground laboratory galleries, the chemical composition of the water is measured. The data is used to evaluate the main parameters of the porewater (pH, Eh, [Ca], [K]) and the resulting solubility of radionuclides.

• Tracer tests (using drill core samples) are undertaken to confirm the results of the previous two experiments and also to appreciate radionuclide mass transport retardation factors.

The above mentioned data are also used for describing the environment of waste packages, Engineered barrier systems and to support the associated design studies.

Particular attention will be given to chemical disturbance due to the materials (concrete, steel) that are candidates to be used during the construction of the repository.

3.3. Characterization of the geomechanical properties of the clay formation

Various types of experiments contribute to this characterization:

• Mechanical measurements in holes drilled from aboveground and laboratory tests on sampled cores, providing additional data to existing information from previous core-holes.

• In situ measurement of the rock mechanical parameters from the underground galleries: rheological behavior investigated with dilatometers in holes drilled in the floor and in the wall; in situ stress measured by overcoring (hydraulic fracturing will also be tested). The resulting data is used to confirm the parameters of the mechanical model.

• Geotechnical survey of all underground openings of the laboratory (convergency)

• Vertical (from a niche located on the main access shaft at - 445 m) and horizontal mine by tests: the objectives of these tests are to understand the hydro-mechanical behavior of the clay at a larger scale and to verify the extent of the modification of the permeability of the clay when shafts are sunk or tunnels mined. Instruments are located close to the future shaft (or gallery) and they monitor changes in the clay during the sinking (or mining).

A plan of successive data acquisition and experiments has been elaborated to make it possible to progressively fit and validate the mechanical models, and to benefit the feedback of one experiment on to the next.

The program also provides for experimental study of:

• Response of the clay formation to ventilation.

• Response of the clay formation to heating.

3.4. Hydrogeological characterization of the site

The characterization of the site hydrogeology is attained by the realization of deep boreholes for data acquisition, in addition to those drilled in the 1994–1996 reconnaissance phase. Some of these boreholes situated in the vicinity of the shafts will be used to monitor hydraulic disturbance due to sinking (this hydrogeological characterization is done from 2000 to 2003).

*No work (shaft sinking or boreholes) has been undertaken on site since 1996, except hydrogeological monitoring in existing boreholes. Work can only resume once the previously mentioned authorization has been given.*
This data is integrated in the hydrogeological model used to describe the boundary conditions of the Callovo-Oxfordian argilite layer and to appreciate radionuclide transfer to the biosphere.

4. RELATIONSHIP BETWEEN THE RESEARCH IN THE LABORATORY AND THE FEASIBILITY AND SAFETY STUDIES

To prepare the research program, initial design options of a potential repository have been selected, on the basis of field data collected in the 1994–1996 period. The next major milestone for the project is in 2001.4

At this intermediate date (with respect to the 2005 milestone) a scoping exercise of the most critical components of the potential repository will help overview the design related models and assess their sufficiency with respect to the 2005 result. The associated data acquisition plan in the laboratory will be assessed at the same time.

Over the same period, a safety assessment exercise will be carried out (based on the safety evaluation of preliminary designs). This safety assessment step starts by a phenomenological analysis of all components in each life phase (before closure, before resaturation, etc.). The objective is then the identification of the phenomenological models selected to describe each resulting situation.

This helps specify the models to be developed and simultaneously the detailed objectives of the field research to be performed to fit and validate these models. All this makes it possible to analyze the robustness of the design with regard to timescale related uncertainties and to select, describe and calculate safety demonstration scenarios during this 1998–2001 phase, with a potential feedback on the field research program and the modeling strategy.

From 2001 to 2005 the last design phase includes component dimensioning based on phenomenological models as developed. In particular, in the field of reversibility several designs will be developed to meet with a range of possibilities to prolong the duration of the initial retrievability period of the preliminary concepts.

A second full safety assessment exercise will be performed between 2001 and 2004 that will contribute to the repository dimensioning and also which will stabilize the safety approach and the definition of safety scenarios. There is a strong link between the safety assessment and model development, and a strong link between model development and data acquisition in particular for geological formations: all these data are used to evaluate or confirm model parameters.

The last safety phase (2004–2004) aims at assessing the feasibility of a safety demonstration. It incorporates models that have been fitted.

4 Along with feasibility of disposal and safety assessment, a process of waste inventory as input data (both from a quantitative & from a radiological point of view), is also included in this project, however it is not the main issue of the present paper.
FIG. 1. Major phases of the development plan.