PERSPECTIVES FOR DEEP GEOLOGICAL FORMATION DISPOSAL RESEARCH IN FRANCE BEYOND 2006

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ABSTRACT

One finalised aim underlies research conducted on the feasibility of geological disposal: the possibility of having a reversible disposal system available. A model has been drawn up to provide a framework for the analysis and propose possible research content between 2006 and 2015.
This period will correspond to the move from the feasibility to a development, optimisation and detailed study phase. It aims at answering any questions raised by reviewers and develops forward the study of a repository. It will also correspond to the consolidation of scientific data, greater understanding of certain mechanisms and an approach of scientific and technical integration. Another goal of the period 2006-2015 would be to collect elements for a decision on the sitting issue through an extended survey.
This phase of development includes confirmation of the data acquired during the previous phase and over relatively long periods, optimisation of repository concepts and detailed study of their main components, the production of full-scale mock-ups or simulations to validate the main technological design points and refining of data extrapolation methods.

1. Background

The December 1991 Act on radioactive waste management research defines three avenues of research for studying long term management solutions concerning high level long lived radioactive waste. It provides for a milestone in 2006 in order to assess the research conducted over the past fifteen years and define the way forward at the end of this research programme. To this end, Andra submitted the initial and final versions, in June 2005 and December 2005 respectively of its deep geological disposal feasibility report. This report gives a general scheme that could be applied, setting out the underlying assumptions and possible uncertainties. It is based on scientific and technical considerations which, when the time comes, may need to be confronted with the social, political or regulatory framework under which any studies could be conducted.

2. The results of fifteen years research (1991-2005)

At the end of fifteen years of research, the report submitted in 2005 by Andra emphasizes that the basic feasibility of a clay medium repository is achieved. A number of elements support this conclusion.

4.1 The Meuse Haute-Marne site offers favourable geological conditions

The Callovo-Oxfordian layer combines some very useful properties, matching expectations for the design of a repository in a clay medium. Firstly, the layer is very thick (130 metres right below the Meuse/Haute-Marne URL site), with large volumes which are not affected by faults. Its geological history is well-known. Since its deposition this history has been quite undisturbed, which is a major argument for confirming its homogeneity and its extreme stability. Seismicity is very low. The layer contains very little water, whose movement is extremely slow, due to its very low permeability. Physical and chemical characterizations further show that it has a strong ability to retain and trap most

of the chemical elements and radionuclides present in the waste. It is suited to excavation mining techniques and underground construction work only causes moderate disturbances, which do not mean, *a priori*, creating preferential flow paths. There is a wide zone of more than 200 km^2 within which these properties exist in principle (so-called transposition zone). The geological medium therefore intrinsically offers favourable characteristics making it suitable for hosting a repository.

4.2 Architectures have been prepared to take advantage of the favourable geological conditions

Engineering studies have defined simple and robust disposal concepts suited to the characteristics of the argillaceous layer, taking the utmost advantage of its qualities. These concepts include cautious choices leading to design margins. The work has not been pursued to the optimization stage, but has established that the proposed architectures were realistic, capable of being constructed and used for waste disposal without any special difficulty. These architectures contain many arrangements which foster overall safety, such as subdividing the repository in various separate zones. Furthermore, operational safety and safety studies based on lessons learnt from other mining or nuclear facilities show the possibility of safe operation without notable impact on the environment.

4.3 Reversibility at the heart of the investigatory approach and expressed in concrete practical terms

The architectures drawn up for the repository have been chosen with in mind a possible reversibility process under the best conditions possible. Andra has developed an approach to reversible disposal which can be defined as the possibility of gradual, flexible management of the repository in stages. The objective is to allow future generations freedom of decision in waste management. Consequently, Andra has opted not to set a preconceived duration for reversibility. This involves offering as great a flexibility as possible in the management of each stage, allowing for the possibility of maintaining the status quo before deciding on the next stage or going backward. The design of the repository (modular architecture, simplified operation, design and choice of durable materials, etc.) aims at allowing the widest possible choices. A period of reversibility of several centuries could be envisaged through monitoring and conventional maintenance work.

4.4 The safety analysis shows the absence of significant impact on the environment

Would closing the repository be decided, a detailed assessment has been made of its behaviour over time and its possible impact on man and environment. On the basis of the acquired scientific data and the proposed repository architectures, a post-closure analysis of the evolution of the repository has been performed. The evolution of the repository under normal conditions has been represented and modelled using computational tools integrating recent advances in digital simulation (ALLIANCES platform). The objective was to examine the efficiency of the repository safety functions. Using various indicators, the analysis shows that the main safety functions (“preventing water circulation”, “limiting the release of radionuclides and immobilising them” and “delaying and attenuating migration”) were fulfilled by the proposed system. The cautious (conservative), or even pessimistic choices made provide significant safety margins. Thus, all the assessments display a high degree of robustness. The analysis has shown that these conclusions were valid not only in normal situations, representative of the most probable evolutions, but also in altered, therefore considerably more pessimistic, configurations.

At the end of the calculations carried out as part of the safety model under normal evolution, repository performance meets, the dose limits recommended by The Basic Safety Rule III.2.f, with large margins. In conclusion, the safety approach supports the repository feasibility study.

3. The basis of the 2006-2015 program on the disposal in the Callovo-Oxfordian formation

Following its production in June 2005, the “Dossier 2005 Argile” has been extensively reviewed by the French National Review Board (CNE), the French Safety Authority, an international review team established by the NEA as requested by the French Government as well as by the scientific committee

of Andra. A national debate was also organized mainly during the last trimester of 2005 the conclusions of which were synthesised in a report.

These different reports were transmitted to the Parliamentary Office of Assessment of Scientific and Technological Choices (OPECST) and the concerned French authorities in order to prepare the 2006 Act on radioactive waste management which was voted on June 28, 2006. This law provides Andra with new milestones and more specifically indicates that the Agency will have to provide a request for authorization of construction of an underground disposal, that could be evaluated in 2015.
Andra also carefully analysed the evaluation reports in order to take into account the various recommendations in the revised versions of its scientific, technical and experimental programs. The final and detailed organisation of the work which will be conducted by Andra during the next 9 years will be completed by the end of 2006.

4. The 2006-2015 program

The proposed program aims at defining the main detailed design elements of a possible repository and carrying out pre-industrial tests. This includes confirmation of the data acquired during the previous phase and over relatively long periods, optimisation of repository concepts and detailed study of their main components, the production of full-scale mock-ups or simulations to validate the main technological design points and refining of data extrapolation methods. It covers the detailed definition, testing and optimisation of disposal design options.

From a more scientific viewpoint, research essentially deals with two major problems:
- changes in scale. This means examining the validity, at larger scale, of data acquired over limited intervals of time and space, as well as specifying the location that could be envisaged,
- validation of the understanding of phenomena and their interactions (full-scale and *in situ*) and their modelling (detailed analysis of couplings).

From a technological viewpoint, the important issues are related to the construction of full-scale repository infrastructures and as well to handling or monitoring operations. In this respect, the Meuse/Haute-Marne laboratory continues to acquire data in order to confirm the previously obtained ones and conduct technological tests directly within the medium under consideration.

Main efforts will thus be focussed on:
- The qualification of the Meuse/Haute-Marne site, with data validation through long-term experiments, data extrapolation and extended geological survey (borehole drilling and geophysical campaign) in order to delimit as accurately as possible the geological zones of interest to site the possible repository facility.
- The consolidation and initial optimisation of engineering studies, with a view to drawing up a full report on the planned installations and processes, as well as the detailed study of the facility main components,
- The technological testing, and production of industrial scale demonstrators or prototypes,
- The scientific programmes underlying optimisation of concepts and experimental testing,
- The definition of appropriate measuring instruments and operational simulation tools,
- The consolidation of safety assessments and more accurate quantification of safety margins.

4.1 Consolidation and optimisation of engineering studies

The engineering studies conducted in the previous phase have enabled the specific components of a disposal facility (installations and processes) to be basically designed. This new phase will allow an overall and detailed view of the installations necessary for the repository operation:
– the underground structures will be defined more precisely, in terms of their dimensioning, construction methods and equipment, so that they can be reproduced experimentally in the underground laboratory (demonstrators). The aim will be to achieve a technical-economic

optimisation of underground installations. Finally, a detailed definition (plans, dimensioning) and design justification report will be produced;
– the surface nuclear facilities previously studied in terms of their construction and operating principles will be studied in more detail and all the surface arrangements will be briefly examined. This will include nuclear buildings (reception and surface storage of packages, disposal package conditioning facilities, etc.) and technical buildings (current, fluids, etc.);
– the transfer, emplacement and possible retrieval of disposal packages will be studied in more depth, in particular for the design of the necessary systems, which will be tested (demonstrators);
– operating safety studies will be continued linked to the previous ones.

The engineering studies will also have to examine in detail how the different activities fit in with each other, particularly in terms of the timing of construction and operation activities. Special emphasis will be put on the reversibility analysis.

4.2 Accompanying scientific programmes

The design of the repository, particularly its dimensioning, is highly dependent on the way the geological medium responds to the perturbations or disturbances it causes. In this respect, additional studies need to be conducted on several thematic areas. The following should be specifically mentioned:

- detailed understanding of near-field thermo-hydro-mechanical interactions, in particular for C waste (vitrified waste) disposal cells with their large number of interfaces. These studies will be closely associated with technological demonstration activity. They will more specifically deal with the first hundreds and thousands years of evolution of the repository with a special focus on the reversibility period (few centuries)
- the gas management with a better appraisal of their production by packages and of their behaviour within the cells, taking into account coupled effects;
- thermal dimensioning criteria, referring in particular to geochemistry and thermodynamic studies;
- the mechanistic approach to radionuclide transport processes in order to make a link between the different scales of investigation and facilitate data transposition;
- specific formulation of materials (structure concrete, engineered barrier buffer clay and backfill materials) related to their expected performances and their implementation in defined concepts; these studies will also be closely associated with technological demonstration activity;
- the detailed modelling of the behaviour of waste matrix and packages in repository conditions.

4.3 Technological tests, demonstrators and industrial prototypes

Technological testing in the underground laboratory has two aims: on one hand, *in situ* and full-scale testing of structure construction processes and the corresponding techniques and tools; on the second hand, validation under *in situ* and full-scale conditions of the scientific knowledge previously acquired from samples or at intermediate scales. These full-scale tests are part of the progressive change of scale approach linked to design iterations.

To this end, structures could be excavated starting out from the underground laboratory infrastructures. Furthermore, additional exploratory drifts will be excavated. Beyond geological survey, they would provide feed-back for industrial-scale excavation method design (technologies becoming progressively more industrial). Most of these demonstration operations will last beyond 2015.

Several tests are scheduled:

- the construction of C waste cells, for excavation and sleeve emplacement. Waste package emplacement and possible retrieval will also be tested. With the installation of heating devices, thermal behaviour measurements would be recorded, in particular to observe thermo-hydro-mechanical phenomena around disposal cells;
- the construction of a B waste cell, through excavation techniques with industrial scale potential (implementation, performance, safety), for geomechanical characterisation and verification of compatibility with package handling processes;

- the construction of a drift with a normal section (access drifts), in which it will be possible to test the excavation process;
- a full-scale sealing test (for example in the previous drift), including the installation of the anchoring key, seal core emplacement and performance tests.

Beyond the demonstration of construction or closure operations, it is also important to test certain processes or technical devices specific to the operating phase, in order to control their actual performance. For this, prototypes can be made and tested in a surface facility (in the workshop, for example), then possibly later underground beyond 2015.

4.4 Measuring devices and simulation tools

The underground installations of a geological repository will have to be regularly monitored and checked. This involves the observations and measurements necessary for the purposes of maintenance and maintaining safety, on the one hand, and gaining the knowledge of repository behaviour and evolution necessary for a step-wise reversible disposal management, on the other hand. The instrumentation technologies and measuring devices required for this purpose will have to be developed (when they do not exist) or tested *in situ*.

The simulation programme undertaken in cooperation with the CEA during the previous period and aiming at installing a simulation platform, will be continued. The objective is the availability of an effective tool suited to the detailed design and monitoring of a disposal facility. Developments should provide an operational tool for safety calculations, which could integrate the growing complexity of coupled thermo-hydro-mechanical and chemical phenomena as they become understood.

4.5 Qualification of the site: validation of data over the long term, extrapolation of data and geological survey at repository scale

The feasibility phase enables the behaviour of the repository, its components and the surrounding rock to be understood in the medium or long term by extrapolations or mechanistic modelling based essentially on data acquired for the short term. In order to achieve optimisation and reliability of the approach (engineering, safety), the acquisition of experimental data over longer periods of time is essential. To do this, measurements will still be recorded on experiments started before 2006. This will allow long-term records in order to validate the main parameters (geomechanical, thermal, gas transfer, diffusion, etc.). Moreover, new data will be obtained from experiments started before 2006 which had not provided yet complete results; this concerns, for example, long-term diffusion experiments, gas migration tests or observation of the behaviour of materials *in situ*.

It should be possible to transpose data obtained in the underground laboratory to the geographical area within which a repository could be sited. The transposition carried out during the feasibility phase led to the definition of a zone representing a 200 Km^2 equivalent geographical area, in which the data obtained inside the underground laboratory zone can be transposed. Within it, it is necessary to specify a zone with the most favourable geological, hydrological, geochemical and geomechanical characteristics in terms of the confinement provided by the layer and of the hydrogeological pattern. Based on a combination of direct and indirect surveying methods (borehole drilling and 2D high definition seismic measurements), the program will aim at completing the characterisation of this zone, in order to propose a more restricted one which could correspond to a possible repository footprint and on which more detailed geological exploration would be carried out (seismic 3D).

5 Summary

The studies conducted over the 2006-2015 aim to prefigure an industrial scale project. The technical report produced at the end of this phase will give an overview of the planned installation. It will provide its detailed definition, supported by scientific knowledge and technological tests for the most significant elements. Under these conditions, a draft preliminary safety report could be issued. The concerned geological medium will have been surveyed and all the elements necessary for sitting a possible facility will be available.