

Towards a sustainable management of radioactive waste

Background to the SAFIR 2 report

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The technical survey of the SAFIR 2 report and the document "Towards the sustainable management of radioactive waste", which places this report in a wider context, can be consulted on the website of ONDRAF/NIRAS: www.nirond.be.

1 Context

All over the world, scientists have been looking for many years for a safe and final solution for the radioactive waste produced by our society. At an international scientific level, it is estimated that the final disposal of the waste in stable geological formations can constitute an appropriate and safe mode of long-term management of the waste. The main arguments put forward are that deep disposal can sufficiently isolate man and the environment over very long periods, and that final disposal does not impose an excessive technical, financial or social burden on the future generations. It is generally accepted that the generation that benefited from the nuclear technology should also support the burden without transferring it to the future generations.

In Belgium, the problem of the long-term management of radioactive waste has been on the agenda for many years. Since 25 years, intensive research has been done on the possibility of an underground repository for high-level and/or long-lived waste (category B & C waste) in clay layers. Belgium is a pioneer in this field. Since the beginning of the 1980's, our country has had at its disposal, as the first in the world, an underground research laboratory in clay (in particular in the Boom clay at a depth of 225 metres under the site of the Centre d'Etude de l'Energie Nucléaire (nuclear research centre) (CEN·SCK) in Mol. The research which is being carried out there, should allow to know whether the final disposal of high-level and/or long-lived waste in such clay layers, can guarantee the protection of man and the environment in the long term. The protection must indeed be effective as long as the radioactive substances in the waste are harmful, in other words, as long as necessary for the radioactivity of the waste to decrease by natural decay to a level that the competent authorities deem acceptable for public health.

2 The SAFIR 2 report

ONDRAF/NIRAS carries out many studies in cooperation with the Centre d'Etude de l'Energie Nucléaire (nuclear research centre) (CEN·SCK) and various engineering consultancies and universities, to verify whether final disposal in deep clay layers can guarantee the protection of man and the environment in the long term. These studies have been going on in Belgium for over 25 years.

The report that ONDRAF/NIRAS submits today, presents the current state of the scientific and technical research carried out over the last ten years (1990-2000) on the possible final disposal of high-level and/or long-lived radioactive waste (category B & C waste) in clay layers.

The SAFIR 2 report – SAFIR stands for *Safety Assessment and Feasibility Interim Report* – follows a first report that was published at the end of the 1980's and surveyed the state of the experience and knowledge acquired since 1974. The SAFIR 2 report must allow the supervising minister of ONDRAF/NIRAS and all the actors involved, in particular the safety authorities, to evaluate the progress made during the period 1990-2000, regarding the feasibility and the safety of an underground repository in deep clay layers for high-level and/or long-lived radioactive waste as a possible solution. The SAFIR 2 report was evaluated by a committee of Belgian experts, created at the initiative of the board of directors of ONDRAF/NIRAS, to accompany the finalization of the report and to make recommendations for the next phase of the work programme of ONDRAF/NIRAS concerning deep disposal. At the request of the government, the report will be subject to an international examination in the course of 2002, by the Nuclear Energy Agency (NEA) and the Organisation for Economic Co-operation and Development (OECD).

3 The present research programme and its achievements

The study of the possibility of a repository for radioactive waste in clay layers, represents an innovative project in many ways. Consequently, it has to go through all the stages that characterise a project of this type: fundamental research, methodological research, applied research, defining the components of the technical concept and ensuring their consistency, characterising the host formation and the interactions between the materials of the concept and the disposal environment, developing methodologies for evaluating performance and safety, pilot projects, implementing a preliminary project, applying for authorisations, and so on.

Ever since the Centre d'Etude de l'Energie Nucléaire (nuclear research centre) (CEN-SCK) launched the research programme in the 1970's, major achievements have been made in several of the areas mentioned above. The Belgian programme has also benefited from the construction and operation of an underground laboratory in the Boom clay in Mol at an early stage of its development.

So far, the work has focused on the Boom clay in the Mol-Dessel region and, to a lesser extent, on the Ypresian clays in the Doel region. The work concerns the potential host rock and hence in no way implies the choice of a site, which involves many other factors, both technical and social.

Today, research and development is still of an essentially methodological character. It aims no less than to establish that a technical solution is possible on Bel-

gian territory for the final disposal of high-level and/or long-lived waste. It consists of two main activities:

- developing and finalising all the methods required for assessment: waste characterisation, characterisation and assessment of a host formation, performance and safety assessments, identification of remaining uncertainties, etc.;
- assessing the feasibility of the solution and the elements supporting its safety, and developing a repository architecture, based hypothetically on a benchmark case: the Boom clay formation and the nuclear zone in Mol-Dessel.

Research has reinforced the confidence in clay as a natural barrier, and confirms that deep disposal in poorly indurated clay (such as the Boom clay), remains a conceivable option. The work carried out over the last ten years has also allowed to place great confidence in:

- the durability of glass as a matrix for conditioning;
- the possibility of digging the necessary underground facilities;
- the methodology for assessing the radiological safety in the long term.

Without questioning the basic choice of the Boom clay, the report states that certain important questions still have to be answered. It is therefore premature to be making decisive statements about the technical feasibility of a repository in this host formation. The same goes for the Ypresian clays.

4 Social integration

The work performed until now can only be really validated if it is presented in and supported by a decision-making context, which meets the expectations of a modern society. This context does not exist at present and should be put in place to find a socially acceptable solution. However, the dialogue structures that should enable this, do not yet exist. Establishing such a dialogue is therefore a prerequisite if one wishes to continue searching for a solution without the risk of not being able to put it into practice.

In order to get off to a good start, the dialogue must be preceded by an exploratory phase during which a first definition of the problem will be made, the stakeholders will be identified, and the co-definition of the decision-making process and its main stages will be attempted.

5 Towards an integrated action programme

Any sustainable management approach should endeavour to respect the principle of equity between present and future generations and promote economic development, whilst ensuring environmental protection and social well-being. Any sustainable development policy must include these three dimensions: economic, environmental and social.

A major effort is to be made to remedy the de facto lack of dialogue with the various stakeholders at all levels. A balance between the technical approach and the social approach, which does not exist at the moment, must be reached.

The future work programme of ONDRAF/NIRAS will have to focus on:

- preparing and holding a dialogue at all levels on:
 - identifying the various stakeholders wishing to take part in the dialogue;
 - defining alternative options or ones that complement those now being considered for inclusion in the programme;
 - working out, in agreement with the stakeholders, a decision-making process;
- defining and implementing the future methodological technical programme, taking into account the recommendations of the consultative scientific reading committee, by extending it to include the options that emerge from the dialogue.
- The different stages of the technical methodological research programme after 2003 will be determined on the basis of the SAFIR 2 report and the recommendations of the scientific reading committee, as well as on the international evaluation. This programme will include all the research still required for the options being considered (Boom clay, Ypresian clays) and those that would be decided upon at the end of the dialogue preparation stage. This research will make it possible to collect all the elements required to be in a position to embark upon the chosen preliminary project(s).

Once the methodological programme has been carried out, all the scientific and social elements will be available to enable the government to make the final decisions about the option(s) chosen and the site(s) where this option should be implemented.

6 Conclusion

The technical aspect of the long-term management of high-level and/or long-lived waste is now well defined. Conditioned waste is stored in buildings designed for this purpose. Important teams of experienced scientists and engineers are looking for a final solution for the option of final disposal in a poorly indurated clay layer, the Boom clay in Mol-Dessel as reference host rock, with the Ypresian clays formation in Doel as an alternative. The necessary funds for implementing this solution are being secured as the waste is being delivered. Other alternatives may become available and will, of course, in turn have to undergo the necessary evaluations. At present, nothing indicates that one or more solutions cannot be developed by the time the waste is ready to start leaving its temporary warehouses, i.e. around 2050. The high-level vitrified waste must cool down for a period of at least 50 years before it can be disposed of in a clay layer.

It also involves a large number of scientific and technical disciplines, including geology and hydrogeology, civil and mining engineering, geochemistry, the chemistry of radionuclides, material science, as well as statistics and numerical analysis. Its implementation, from the start of the phase of methodological research and development to the closure of the repository and the subsequent period of institutional control, will take several decades and will necessarily be conducted stepwise.

The design and implementation of an underground repository for the long-term management of high-level and/or long-lived waste is a complex and lengthy process. Although the general objective is easy to formulate – protect man and the environment against the potential hazards of radioactive waste both in the short term and in the long term – the solution is much more difficult to conceive. It must indeed remain safe during long periods of time that exceed the habitual time scales of our society. This implies that the solution can hardly be based on the experience of similar projects.

The implementation of a repository, from the beginning of the methodological research and development phase to the closing of the repository and the following period of institutional control, requires moreover decades and must necessarily be carried out in several stages. The concrete execution of a final disposal solution is therefore not for tomorrow.

The method to arrive at a feasible technical and economic, safe and socially accepted final disposal solution, consists in acting iteratively within a gradual, flexible and stepwise process. This process aims to gather in a coherent manner the results of the research and development work undertaken in all the concerned technical, economic and social fields, as well as the evolutions on a legislative and regulatory level.

So far, society has not yet had the chance to interact with the institutional actors on the options under consideration for the long-term management of high-level and/or long-lived waste. However, in conformity with the principle of good governance, the participation of society must be organized in the context of a real dialogue open to all actors. This implies the co-production of decision-making elements by all the parties, as there can be no agreement on the result if there is, on the one hand, no common analysis of the contents of the limits of the problem put forward, and on the other hand, no agreement on the decision-making process to be applied and the rules to be followed to reach a decision.

Appendix: additional information

Objectives of the SAFIR 2 report

The SAFIR 2 report has three objectives:

- to provide the authorities, and all the other parties concerned, with a structured synthesis of the available technical and scientific information relevant to the final disposal of category B & C waste in a poorly indurated clay formation, in order to enable them to evaluate the progress made in terms of technical feasibility and long-term radiological safety;
- to intensify interaction with the nuclear safety authorities, Agence Fédérale de Contrôle Nucléaire (Federal Nuclear Control Agency) (AFCN), so as to reach an agreement on the research efforts still required and on the principles of safety assessments, and to specify the modes of enforcement of the regulations that are applicable to the specific case of deep disposal;
- to constitute one of the technical and scientific bases for a broad dialogue with all of the parties concerned by the long-term management of radioactive waste.

The three main points of the methodological research and development programme

- first phase (1974-1989) focusing on the digging aspects of underground facilities in poorly indurated clay at a depth of more than 200 metres (a world première);
- second phase (1990-2000) focusing on the definition of a methodology to evaluate the long-term radiological safety of an underground repository, as well as the qualities of the natural barrier of the Boom clay concerning the migration of radioactive products. This second phase, described in the SAFIR 2 report, takes account of the recommendations of the commission that was created by the supervising minister to analyse the results of ONDRAF/NIRAS presented in the SAFIR report (1989);
- third phase (2001-2017) focusing on the aspects of the life-size and underground demonstration of the feasibility of the studied solution, on the integration of all of the available data and on the design of the repository architecture for all the types of waste to be disposed of in the underground.

Priorities for the third phase of the methodological research and development programme

- demonstrating the feasibility of implementing the disposal facilities;
- refining the understanding of the processes of radionuclide retention at work in the Boom Clay and of the evolution of the retention properties in this formation;
- analysing the heterogeneities and discontinuities in the Boom clay and their effect on groundwater flows and on radionuclide migration;
- analysing the effect on groundwater flows in the Boom clay of changes in the regional hydrogeological conditions within the surrounding aquifers;
- studying more in detail the aspects of chemical, biological, and physical compatibility of all of the materials in contact with the host formation, and of the different disturbances induced by the various waste classes;
- reviewing the choice of material for the packagings/overpacks and developing an integrated approach to defining the engineered barrier system based on preventing corrosion of the packaging/overpack;
- creating a systematic and system-oriented design methodology for the disposal facilities for all the waste classes, especially for the most detrimental ones;
- analysing the effect on the repository, on the host formation, and on the safety of gas generation by the waste (mainly the category B waste), and evaluating ways in which the repository design might address these;
- studying and demonstrating methods that can be used to characterise the waste and to verify and confirm their composition and heat emission. The nature and extent of these operations must be proportional to the need to apprehend the waste with a view to its deep disposal;
- improving the methodology used to assess long-term safety, in particular as regards identifying and addressing uncertainties and alternative safety and performance indicators, and defining robustness indicators;
- defining and developing a long-term management and transfer system of the knowledge acquired enabling, in particular, the traceability of decisions and technical choices made, and the transfer, integration, and synthesis of multidisciplinary information.

Definition of category B & C waste

The radioactive waste of category C, which is moderately to highly heat emitting, is high-level and mostly long-lived waste. The radioactive waste of category B, has a low heat output and is long-lived waste.

Radioactive waste today

Nowadays, radioactive waste is temporarily stored in buildings specially equipped for this purpose. This is, however, not a final solution, as these buildings would have to be checked at regular intervals, maintained and even possibly renewed or replaced by other buildings. In this way, the future generations would have to occupy themselves with waste that they did not produce themselves.

Final disposal

Final disposal means placing treated radioactive waste in a specific and authorized infrastructure with no intention of retrieving it. The conditioned waste is disposed of in such a way that it will require no intervention by future generations.

Deep disposal implies placing a series of barriers between the waste and the biosphere, so as to protect man and the environment against the risks constituted by the waste.

General concept for an underground repository

To protect man and the environment in the long-term against hazardous waste, two things must be avoided: firstly, that the radiation emitted by the waste does not reach the environment and does not cause any damage to man and the environment, and secondly, that the radioactive substances do not end up in the environment. The safety of a deep disposal facility is based on a succession of various barriers that isolate the waste from the environment. The system consists in a combination of natural and artificial barriers that collaborate and complete each other to achieve the necessary long-term isolation of the waste by preventing or limiting the movement of radioactive substances from the infrastructure of the repository to the biosphere.

To this end, the radioactive waste is first of all transformed, by using an adapted technology, into a solid, stable and compact product in which the radioactive substances are immobilized and confined in a suitable material to prevent their dispersion in the biosphere. The high-level radioactive liquids are treated by mixing the liquids with glass at a temperature of over 1000 °C, which produces a block of solid and homogeneous glass in which the radioactive substances are integrated into the molecular structure of the glass.

The deep disposal concept put forward by the scientists, consists in burying the radioactive waste in a deep underground, in a stable layer with low permeability, and in an adapted infrastructure of excavated galleries in which the drums of treated waste are placed. The long-term safety is mainly based on the capacity of the host rock to isolate the radioactive substances from man and the environment during hundreds, end even thousands of years – long enough for the radioactivity of the high-level and long-lived waste to decrease.

Basic principles for the design and implementation of an underground repository

For the category B & C waste, the option of concentration and confinement is being considered at an international level. This option may be implemented by storing the waste in specially designed buildings on the surface, or by disposing of it in an appropriate underground facility. While the former solution would require future generations to take active maintenance and monitoring measures for a long period, the latter could be designed from the outset so as to be passively safe and thus require no intervention in either the short or the long term. As most countries confronted with the problem of the management of high-level and/or long-lived waste, this is the solution ONDRAF/NIRAS has always studied as the reference solution.

An underground repository must remain safe for periods that go far beyond those normally comprehended by our society. This implies that it can hardly be based on the experience acquired from other similar projects. It also involves a large number of scientific and technical disciplines that necessarily intervene, including geology and hydrogeology, civil and mining engineering, geochemistry, the chemistry of radionuclides, material science, as well as statistics and numerical analysis.

To find a solution for final disposal that is both safe, technically and economically feasible and socially accepted, it will be necessary to work iteratively within the framework of a gradual, flexible and stepwise process. This process aims to bring together in a coherent manner the results of the research and development work performed in all of the technical, scientific and social fields concerned, as well as the legislative and regulatory evolutions. In this way, the knowledge and design of the final disposal system will be continuously improved and the safety assessments will be refined. The process therefore incorporates aspects of understanding, design, construction, operation, and closure with a view to identifying the elements requiring further investigation at the appropriate time. For example, the architecture of the repository has a direct impact on

the manner in which the waste must be placed, and vice versa. The conclusions of the safety assessments, which determine each time the start of the next implementation phase, and the evolution of the architecture of the repository, raise in turn issues for further research, and so on. The reference architecture will thus gradually evolve towards the final architecture. The same applies to the safety assessments.

Objective of the management of radioactive waste

The objective of the management of radioactive waste is to protect man and the environment from the potential hazards of ionizing radiation emitted by the waste. To achieve this, the untreated waste must be transformed into a compact and chemically stable product, which confines the radioactive substances. This end product must be isolated from man and the environment as long as there remains a health risk.

The aim of the long-term management of radioactive waste is to protect man and the environment in all circumstances against the potentially harmful effects of the radioactivity from the radioactive waste.

The principles of radioactive waste management

The principles of radioactive waste management established by the International Agency for Atomic Energy (IAEA), are translated by a double objective regarding final disposal.

- protect man and the environment. The repository must protect man and the environment from the risks that the radioactive waste may constitute by concentrating and confining it for as long as necessary;
- limit the transfer of the burden to future generations. The repository must provide a passive protection, i.e., a protection that ultimately will require no intervention by future generations.

HADES and EIG EURIDICE

Since 1980, scientists work in an underground laboratory built in one of the Belgian clay layers in order to verify whether it could be suitable as a final destination for high-level and/or long-lived radioactive waste. The laboratory HADES, which is the name of the Greek god of the underworld, is the acronym of "High Activity Disposal Experimental Site". This laboratory is situated in Mol, under

the site of the Centre d'Etude de l'Energie Nucléaire (nuclear research centre) (SCK·CEN). Technicians carry out all sorts of experiments to analyse the clay layer and study the behaviour of different materials in contact with this layer.

In December 2000, the Economic Interest Grouping (EIG) EURIDICE was created in Mol. EURIDICE – which stands for European Underground Research Infrastructure for Disposal of nuclear waste In Clay Environment – was already set up in 1995 under the name EIG PRACLAY and is a joint venture between ONDRAF/NIRAS and the SCK·CEN.

The EIG EURIDICE is situated in Mol, Boeretang 200, on a site for which the SCK·CEN granted a right of building to the EIG.

The main missions of the EIG EURIDICE are:

- to contribute to the feasibility studies on the final disposal of radioactive waste in clay layers;
- to manage and exploit the underground laboratory HADES;
- to extend the underground laboratory HADES;
- to carry out the PRACLAY experiment that must contribute in a major way to the research on the feasibility of deep disposal in clay;
- to open up the underground laboratory to international cooperation.

The extension works of the underground research laboratory HADES are under way at the moment. The construction of the second access shaft (left on the picture) was completed at the end of 1999 and the connecting gallery with a total length of about 80 metres at a depth of 225 metres linking the existing underground laboratory, is being excavated at the moment.

Once the HADES laboratory will have been extended – currently foreseen for 2003 – it is the intention to carry out national and international experiments in this new part of the laboratory. One of the main experiments that will be carried out in the new part of the laboratory is the PRACLAY experiment of which the studies will start according to the present planning in 2004. This experience aims to demonstrate the technical feasibility of the final disposal of high-level vitrified radioactive waste in a deep clay layer.

The geological time scale

When we speak of several hundreds, thousands, tens of thousands or even hundreds of thousands of years, it seems to us, human beings, infinitely long. This is because we are used to think in the short term: seconds, minutes, hours, days,

years. But there exists another notion of time, the geological time scale, which makes a connection with the creation and the evolution of the universe and the earth. When one talks in this time scale of thousands, tens of thousands or even hundreds of thousands of years, it is a mere trifle.

About 3.5 million years ago the first anthropoids appeared on the earth, the era of the dinosaur dates back to about 245 million years, the creation of the earth to 4,600 million years and the origin of the universe to 15,000 million years. If we assume that the universe was created 12 hours ago, we only appeared in the last few seconds.

The Boom clay was formed about 30 to 35 million years ago. Nothing indicates that the stability of this layer will be disrupted during the period necessary for the radioactive waste to become harmless.