ONDRAF/NIRAS

Executive Summary of the Waste Plan

for the long-term management of conditioned high-level and/or long-lived radioactive waste and overview of related issues

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Executive Summary

In Belgium, the legislator entrusted the management of radioactive waste to a public institution with legal personality: the Belgian Agency for Radioactive Waste and Enriched Fissile Materials, known by the French/Dutch acronym ONDRAF/NIRAS. This management must ensure the protection of man and the environment against the risks associated with this waste, and therefore includes an important long-term management pillar. Indeed, conditioned short-lived low-level and medium-level waste, called category A waste, presents a risk for man and the environment for hundreds of years to come. A common feature shared by the other conditioned wastes managed by ONDRAF/NIRAS, the conditioned wastes from categories B and C, also called B&C waste, is that they contain such quantities of long-lived radionuclides that they present a risk for tens to hundreds of millennia. It concerns high-level and/or long-lived wastes.

The long-term management of radioactive waste falls under the exclusive competence of ONDRAF/NIRAS. In accordance with the legal framework, this long-term management must ensure that the waste is disposed of in the long-term management facility with no *intention* of retrieving it, this facility being then its final destination. However, the fact that the waste is not intended to be retrieved does not necessarily mean that it is impossible to retrieve it or to carry out controls.

Contrary to the situation for category A waste, no institutional policy has yet been validated in Belgium for the long-term management of existing and planned B&C waste, including non-reprocessed used nuclear fuel declared (or likely to be declared) as waste, as well as the excess quantities of enriched fissile materials and plutonium-bearing materials (excluding fuel) declared (or likely to be declared) as waste.

> *In the rest of the text, the phrase "B&C waste" must be understood as also referring to non-reprocessed used nuclear fuel declared (or likely to be declared) as waste, as well as excess quantities of enriched fissile materials and plutonium-bearing materials (excluding fuel) declared (or likely to be declared) as waste.*

The interest and the quality of research, development and demonstration (RD&D) activities in the field of long-term management of B&C waste, initiated in 1974 by the Belgian Nuclear Research Centre (SCK•CEN) and transferred under the responsibility of ONDRAF/NIRAS a decade later, have been confirmed several times as from 1976 by different commissions and working groups asked by institutional bodies to advise on ongoing studies in the field of long-term management of B&C waste or on energy policy issues, without, however, the direction taken — *geological disposal in poorly indurated clay* (in Belgium, Boom Clay or Ypresian Clays) — being *formally* confirmed or refuted at the federal level.

It is the responsibility of the countries that have signed the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, including Belgium, to have long-term management policies for these materials. Following the ratification of this convention, Belgium transposed it in its legislation in 2002. Independent of the countries' future energy policies, this national responsibility is also one of the basic principles laid down in the European Directive of 19 July 2011 for the responsible and safe management of spent fuel and radioactive

waste ("Waste" Directive). (The Waste Plan does not take this very recent Directive into account, except by adding an annex mentioning the key points of the Directive directly related to the Waste Plan and providing a first analysis of the Waste Plan's contribution to compliance with the Directive requirements.)

Besides, an institutional policy for the long-term management of B&C waste is essential in many respects, in particular to enable ONDRAF/NIRAS to focus the RD&D activities still required according to the final destination of this waste, to help it determine and optimize all the upstream aspects of management, to enable it to apply the "polluter pays" principle more concretely than today, to lift the current uncertainty relating to storage duration in the municipalities where this waste is currently temporarily stored, and to avoid shifting the management responsibility, including all associated burdens (technical, financial, decision-making, radiological, etc.), on to the future generations, in accordance with the intergenerational equity principle put forward in the Joint Convention and the "Waste" Directive.

1 Waste Plan: motivation and scope

Whereas in particular

- ONDRAF/NIRAS is legally bound to have a general programme for the long-term management of radioactive waste;
- a long-term management policy for B&C waste is *necessary*;
- ONDRAF/NIRAS's RD&D programme in the field of long-term management of B&C waste, which is in line with the corresponding international recommendations, has reached an advanced level of technical maturity, which makes it *possible* to make a general policy decision in this field;
- ONDRAF/NIRAS in 2004 was entrusted by its supervisory authority to prepare and start a societal dialogue at all levels on the long-term management of B&C waste and to assess all possible strategies for this management in order to decide on the management solution to be implemented;
- the law of 13 February 2006, on the one hand, requires that the general programme for the long-term management of radioactive waste be subject to an environmental impact assessment and that this assessment (strategic environmental assessment or SEA) include an assessment of the likely impacts of the "reasonable alternatives" and, on the other hand, provides for public participation in the development of this programme;

ONDRAF/NIRAS has taken the initiative to compile in a single document, the *Waste Plan*, all elements necessary to enable the Government to make, with full knowledge of the facts, a *decision in principle*, i.e. a *general policy* decision or a *general guidance* decision, relating to the long-term management of B&C waste. Such a decision is not a decision for the immediate implementation of a specific solution on a given site.

The Waste Plan focuses on the long-term management of B&C waste, encompassing only existing waste and waste of which the production is planned, mainly within the scope of the current electronuclear programme. According to ONDRAF/NIRAS 2009 estimate, the volumes of B&C waste to be managed by 2070, i.e. by the end of the activities relating to the dismantling of all existing nuclear facilities or of all nuclear

facilities of which the construction was planned as of 31 December 2008, are the following:

- 11 100 or 10 430 m^3 of category B waste, depending on whether the current suspension of commercial used fuel reprocessing is lifted or maintained. This waste originates mainly from research activities, nuclear fuel production, reprocessing of used fuel and dismantling of nuclear power plants and research and fuel production facilities.
- 600 or 4 500 m^3 of category C waste, depending on whether the current suspension of commercial used fuel reprocessing is lifted or maintained. This waste is vitrified waste resulting from reprocessing commercial used fuel and non-reprocessed used fuel declared as waste.

An important part of this waste already exists or will inevitably be produced.

The long-term management of category A waste is mentioned in the Waste Plan for the record, since the management solution to be carried out for this waste — surface disposal on the territory of the municipality of Dessel within the scope of an integrated project providing added value for the region — was determined by a decision of the Council of Ministers on 23 June 2006.

Finally, the Waste Plan identifies a series of questions the answers to which are not a matter solely for ONDRAF/NIRAS but are likely to impact on the long-term management of B&C waste (such as the status — resource or waste — of commercial used fuel as well as of enriched fissile materials and plutonium-bearing materials excluding fuel), or even on its management activities in general. Thus, the Waste Plan touches on the development of one or more management systems complementary to the existing system in order to ensure the long-term management of substances that currently do not have radioactive waste status but could acquire it later on, or of radioactive waste for which no application has yet been submitted in order for ONDRAF/NIRAS to take charge thereof.

ONDRAF/NIRAS's general programme for the long-term management of radioactive waste will ultimately include, in addition to the Waste Plan, one or several other dedicated plans covering the management of all substances that have or will have radioactive waste status. These plans will be established as the corresponding dossiers reach a sufficient level of maturity.

2 Development of the Waste Plan and procedural aspects

With a view to developing its Waste Plan, ONDRAF/NIRAS decided to conduct an assessment of the possible options for the long-term management of B&C waste and a societal consultation which are broader than required under the law of 13 February 2006.

- In the Waste Plan and the SEA on which it is based, all the possible options for the management of B&C waste were considered in the broadest possible way.
- The development of the document which preceded the Waste Plan, called "draft Waste Plan", and of the SEA was improved using the results of a societal consultation organised on ONDRAF/NIRAS's initiative long before the consultation process imposed by the law of 13 February 2006.
- The assessment of these options within the scope of the SEA was not limited to environmental impacts but also included, insofar as possible, the environment and safety, technical and scientific, financial and economic, and societal and ethical dimensions.

The Waste Plan and the SEA are the outcome of a multi-step development process regulated by the legal procedure laid down in the law of 13 February 2006. In accordance with the provisions of this law, ONDRAF/NIRAS in particular submitted the draft Waste Plan and the SEA for an opinion to the Advisory Committee, called "SEA Advisory Committee", set up by this law, the Federal Council for Sustainable Development, the Governments of the Regions and the public. As it was allowed by law, ONDRAF/NIRAS also submitted these documents for an opinion to the nuclear safety authority (the Federal Agency for Nuclear Control or FANC). In its opinion on the draft Waste Plan and the SEA, the SEA Advisory Committee did not identify any deficiencies regarding the way in which the legal procedure was implemented.

In finalizing the Waste Plan, ONDRAF/NIRAS took into account the official institutions' opinions and the public's comments provided during the legal consultation procedure. In accordance with the provisions of the law of 2006, it also issued a declaration which among others summarizes the way in which the SEA as well as the opinions and comments received were taken into account for finalizing the Waste Plan.

The Waste Plan was adopted by the Board of Directors of ONDRAF/NIRAS, the only authority entitled to do so, on 23 September 2011. *Commencement of its implementation must be validated by a decision in principle at the federal level.*

3 Assessing and comparing options

In the Waste Plan and the SEA on which it is based, all the possible options for the long-term management of B&C waste were considered *in the broadest possible way* (Figure 1). Some options were rejected straight away, as they are in violation of international treaties or conventions to which Belgium is signatory (for instance sea dumping and disposal in ice sheets), and/or the Belgian legal and regulatory framework (for instance disposal by injecting waste in liquid form in deep underground), and/or do no provide adequate safety guarantees (for instance surface disposal). The remaining options, i.e. eternal storage, geological disposal, disposal in deep boreholes, long interim storage with a view to or awaiting "something else", and the option consisting in

continuing the current situation (status quo) were then subjected to a cross-disciplinary assessment within the scope of the SEA and the Waste Plan. The SEA Advisory Committee confirmed in its opinion that the choice of possible options is coherent with the approach adopted in the other countries facing similar problems.

As the Waste Plan aims at making a strategic decision — not at a decision relating to a concrete project — management options were considered in generic terms in the Waste Plan and the SEA, i.e. without linking them to a particular site. This means both documents do not handle any siting issues, nor do they deal a fortiori with the facility design. Consequently, the assessment of the considered options was essentially qualitative and relied on experts' judgements founded on the entirely open knowledge basis available at national and international level and, insofar as possible, on similar studies carried out in other countries and the consequent decisions, as well as on feedback from existing similar facilities in Belgium and abroad. However, quantitative analyses were carried out whenever possible and appropriate. Due also to the strategic nature of the Waste Plan, transboundary environmental impacts were not assessed. The SEA Advisory Committee confirmed in its opinion that such an assessment was not yet possible.

Once the assessment of the options was completed, the various options envisaged for the long-term management of B&C waste were narrowed down to two strategic options: disposal of the waste in an appropriate geological formation, or long interim storage with a view to or awaiting "something else". The eternal storage option proves inadequate to ensure long-term safety, whereas disposal in deep boreholes is not a viable option for the long-term management of the total volume of B&C waste, and the status quo option is not a long-term management solution and does therefore not enable ONDRAF/NIRAS to fulfil its management assignment.

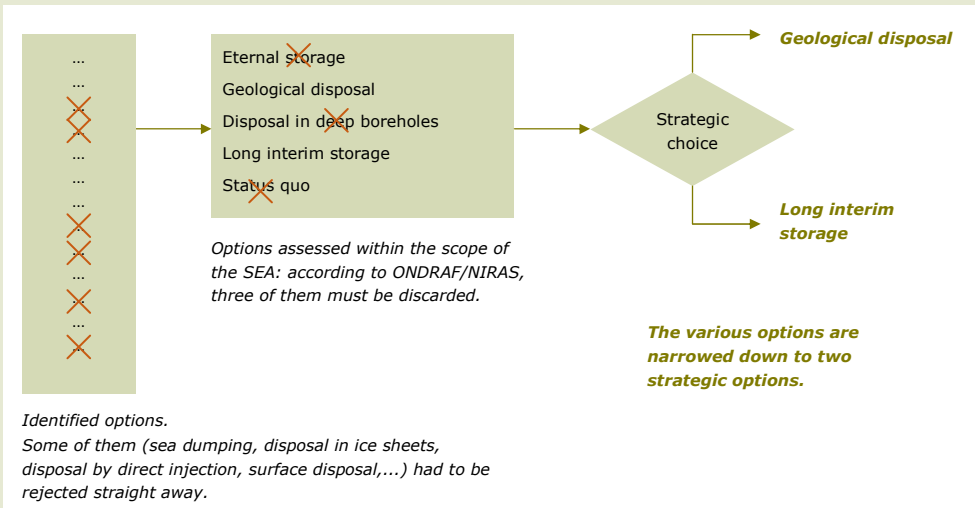


Figure 1 – Gradual process of discarding options that prove inadequate or inappropriate for the long-term management of B&C waste.

The major difference between geological disposal and long interim storage (100 to 300 years) is the fact that a storage facility is not the final destination of the waste and,

therefore, it is not a management solution designed to become definitive, contrary to a geological disposal facility, which can also become a system that can ensure safety in a passive way after complete closure (i.e. without human intervention being necessary, which does not mean that controls are absent or impossible). On the other hand, the operational period (construction, operation, closure) of a geological disposal facility (approximately one hundred years) requires active management and is, in this respect, similar to the operational period of a storage facility.

The comparison between geological disposal and storage during 100 to 300 years reveals two elements which, according to ONDRAF/NIRAS, decisively weigh in favour of geological disposal as a solution for the long-term management of B&C waste (see also Figure 2).

- The *robustness* of geological disposal with respect to future evolutions (societal, natural, etc.), i.e. the fact that the safety of a repository system appropriately designed and implemented is not unacceptably affected by future evolutions. On the other hand, the safety of storage requires active management and is, therefore, particularly dependent on societal evolutions: safety might no longer be ensured if the active management is disrupted.
- The fact that geological disposal shifts *minimum* burdens on to future generations. By contrast, any storage solution de facto transfers the whole management responsibility, including considerable burdens, to the future generations, which will have to decide on a solution that can become definitive, or on a new storage period at the end of the long interim storage period.

According to ONDRAF/NIRAS, a geological disposal facility — progressively developed, implemented and closed, if need be after a period of in situ controls — is the only management solution capable of protecting man and the environment in the long term against the risks associated with B&C waste, and of minimizing the transfer of the burdens to future generations while leaving them some freedom to choose, in particular regarding controls of the repository, closure planning, possible retrieval of waste and knowledge transfer to the next generations. This solution is in line with international recommendations and practices.

CURRENT SITUATION

Interim storage

Planned duration: approx. 75 years
Safety subject to maintenance and controls

The stored waste is to be transferred to a long-term management facility.

Strategic choice of long-term management (part of the decision in principle)

OR

DESIRED SITUATION: Solution ensuring the protection of man and the environment for as long as the waste presents a risk (several tens to hundreds of thousands of years)

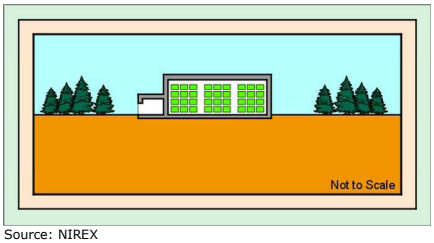
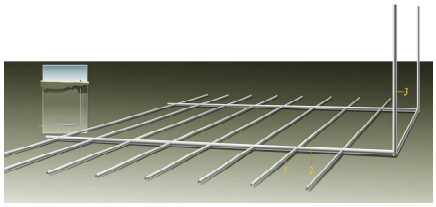
	Long interim storage	**Geological disposal**
	 Source: NIREX	
Safety	■ ensured, subject to continuous maintenance and controls	■ inherent to the system for geological periods of time (million years)
Main uncertainties	■ societal ⇒ cannot be managed (uncertainty whether future societies will continue to ensure the necessary controls with a view to long-term safety)	■ scientific and technical ⇒ taken into consideration in the development and assessment of a robust disposal system; no prohibitive defects have, however, been found during 30 years of RD&D in some twenty countries
Life expectancy of the system	■ limited by technique (a priori to 300 years)	■ ensured by choosing a stable formation
Vulnerability to natural events	■ protection ensured by technique	■ protection ensured by host formation
Transfer of burdens	■ burdens completely shifted on to future generations	■ minimum burdens shifted on to future generations
Retrieval of waste	■ possible at any time	■ possible, but becoming more difficult over time
Controls	■ essential for ensuring safety	■ not essential for safety, but intended to be maintained for a duration still to be determined
Knowledge transfer	■ essential for ensuring safety	■ not essential for safety, but planned
Integration of the scientific and technical developments	■ possible at any time	■ limited to operational period
Polluter pays principle	■ not applicable because the solution which will replace storage is not identified	■ applicable on a concrete basis
Vulnerability to malicious acts	■ basically subject to controls	■ limited vulnerability because of depth
Type of solution	■ not justifiable according to safety authority (FANC)	■ solution recommended internationally
	is thus not a long-term management solution	***is thus a long-term management solution***
	Requires a new decision in principle with a view to a long-term management solution	*Strictly speaking, no further human intervention is required once the facility is completely closed. The combination of "engineered barriers + geological host formation" retains the radionuclides which are finally released from the waste, and in this way protects man and the environment.*

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Figure 2 – Key aspects of the strategic choice between geological disposal and long interim storage.

4 The solution recommended by ONDRAF/NIRAS for the long-term management of B&C waste

For the long-term management of existing B&C waste and of B&C waste of which the production is planned, ONDRAF/NIRAS recommends a *global* geological disposal solution, including a technical solution (section 4.1) that fits into a decision-making process integrating the technical and societal aspects (section 4.2), the development and implementation of which are accompanied by a series of conditions arising from the societal consultation organised on ONDRAF/NIRAS's initiative and from the legal consultation (section 4.3).

4.1 Technical solution for the long-term management of B&C waste

The technical solution recommended by ONDRAF/NIRAS for the long-term management of B&C waste is a solution that can become definitive, namely

- geological disposal (section 4.1.1)
- in poorly indurated clay (Boom Clay or Ypresian Clays) (section 4.1.2)
- in a single facility (i.e. one facility for all B&C waste and built on a single site) (section 4.1.3)
- on Belgian territory (section 4.1.4)
- as soon as possible, the pace of development and implementation of the solution being proportionate to its scientific and technical maturity, as well as to the public support it receives (section 4.1.5).

4.1.1 Geological disposal

Geological disposal

- is in line with ONDRAF/NIRAS's legal assignment, as it provides a final destination for B&C waste;
- is applicable to all existing and planned B&C waste;
- is considered by radioactive waste management organisations and safety authorities at national and international level as feasible and capable of ensuring the protection of man and the environment for several hundred thousand years in a robust way, this in an intrinsically passive manner;
- is confirmed by the results of the multidisciplinary analysis of the possible management options carried out within the scope of the SEA as *the only solution for the long-term management of B&C waste and certainly as the safest from a radiological point of view, the strongest in terms of future societal and natural evolutions and the most appropriate to protect man and the environment in the long term*;
- minimizes the burdens transferred to the future generations, in particular radiological risks, environmental impact and responsibility for ensuring safety, making decisions and ensuring financing;
- can be financed on the basis of the "polluter pays" principle;

- has been chosen by all countries that have an institutional policy for the long-term management of their B and/or C waste. The United States has operated since 1999 a geological disposal facility for its category B military waste, and Finland, France and Sweden are, in principle, only 10 to 15 years away from starting the industrial operation of a geological disposal facility.

4.1.2 In poorly indurated clay (Boom Clay or Ypresian Clays)

Poorly indurated clays, in particular Boom Clay and Ypresian Clays, are the geological formations in Belgium that seem to present the best intrinsic properties to ensure the functions expected from a natural barrier, i.e. functions of long-term isolation, confinement and retention of radionuclides and chemical contaminants present in a geological disposal facility. A disposal system (host formation + repository + waste) appropriately designed and implemented in these clays can ensure safety in the long term.

Poorly indurated clays as a long-term natural barrier preventing the migration of radionuclides and chemical contaminants

Thanks to their properties, poorly indurated clays are high-quality natural barriers preventing the migration of radionuclides and chemical contaminants towards the surface environment.

- They present a *very low permeability*. There is therefore practically no water movement in these clays and thus no radionuclide and chemical contaminant transport via this medium. As a result, transport is essentially diffusive, which means species migrate under the influence of their concentration gradient, not under the influence of the interstitial water movement.
- They have a *strong retention capacity* for many radionuclide and chemical contaminant (sorption capacity, favourable geochemical properties,...). Their migration through the clay is thus considerably delayed.
- They are *plastic*. Therefore, any fractures and fissures that could occur in the clays, in particular by excavation activities, tend to close by themselves (self-sealing capacity).

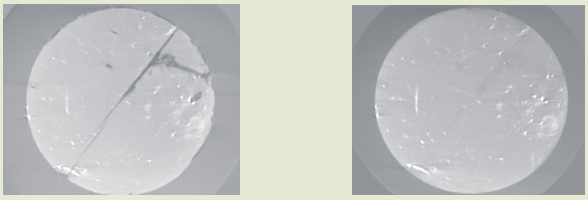

Illustration of the self-sealing capacity of Boom Clay. Left: clay sample in which a fracture has been induced. Right: the same sample 4 hours after hydraulic saturation: the fracture has closed.

The entire Boom Clay formation (about 100 metres thick) consists of different layers more or less rich in clay. However, radionuclide and chemical contaminant transport properties are very homogeneous almost throughout the entire thickness of the Boom Clay. In addition, Boom Clay and Ypresian Clays have a simple geological structure, which makes their characterization easier.

Finally, Boom Clay and Ypresian Clays are hydrogeologically, geochemically and mechanically stable over geological periods of time, i.e. millions of years. Their components have remained unchanged since shortly after the deposition of the formations. Over this entire period, natural changes (seisms, sea level fluctuations, glacial periods, etc.) have not altered their favourable properties.

Disposal system description

The essential elements on which ONDRAF/NIRAS relies to design a disposal system for B&C waste in poorly indurated clay ensuring operational and long-term safety can be summarized as follows.

- *Long-term safety:*
  - *Confinement* of category C waste must be ensured by engineered barriers (manmade barriers) for the period during which the host formation properties could become temporarily perturbed, in particular due to the rise in temperature (thermal phase). This period ranges from several hundreds of years for vitrified waste to several thousands of years for non-reprocessed used fuel (provided that it was first cooled in surface storage for 60 years).
  - *Isolation* of the repository from external perturbations, such as climate changes, seisms or human activities, must be ensured by the clay layer and its geological environment.
  - *Delay* in the migration of the radionuclides and chemical contaminants which will finally be released from the waste and the engineered barriers is essentially ensured by their retention in the clay.
  - Design of the repository, including technique and material choices, is carried out in such a way that the clay, which is the most important barrier with a view to long-term safety, is *not unduly perturbed*.
- *Operational safety:*
  - The engineered barriers must ensure a *radiological shielding* of the waste for the entire operational period (about 100 years), from the moment the conditioned waste is post-conditioned aboveground to form supercontainers or monoliths (see below). They also aim at reducing the contamination risks in the repository.

The geological repository considered for B&C waste consists of a network of horizontal galleries built at mid-thickness of the clay layer, at a sufficient depth (Figure 3). Shafts lead to a main gallery which gives access to the disposal galleries, of smaller diameter. These galleries are divided into several sections dedicated to groups of wastes with similar characteristics (for instance their thermal output, their chemical composition or the nature of their conditioning matrix).

The system of engineered barriers considered for category C waste is based on the use of supercontainers aimed at ensuring full confinement of the radionuclides and chemical contaminants during the thermal phase. For handling reasons, category B waste is placed in concrete caissons and subsequently embedded in mortar to form monoliths. The supercontainers as well as the monoliths ensure a radiological shielding to protect workers during operation and closure of the repository.

After emplacement of the waste, empty spaces in the disposal galleries are backfilled with materials chosen for their capacity to contribute to the system's overall safety. All access galleries and shafts are backfilled and sealed at the end of the underground operations, if need be after a period of in situ controls. The system is then in a passive state.

After closure, the geological repository can be controlled from the surface, and the future generations can prolong controls as long as they wish. Besides, controls will be compulsory in case of disposal of used fuel, in order to prevent risks of nuclear proliferation.

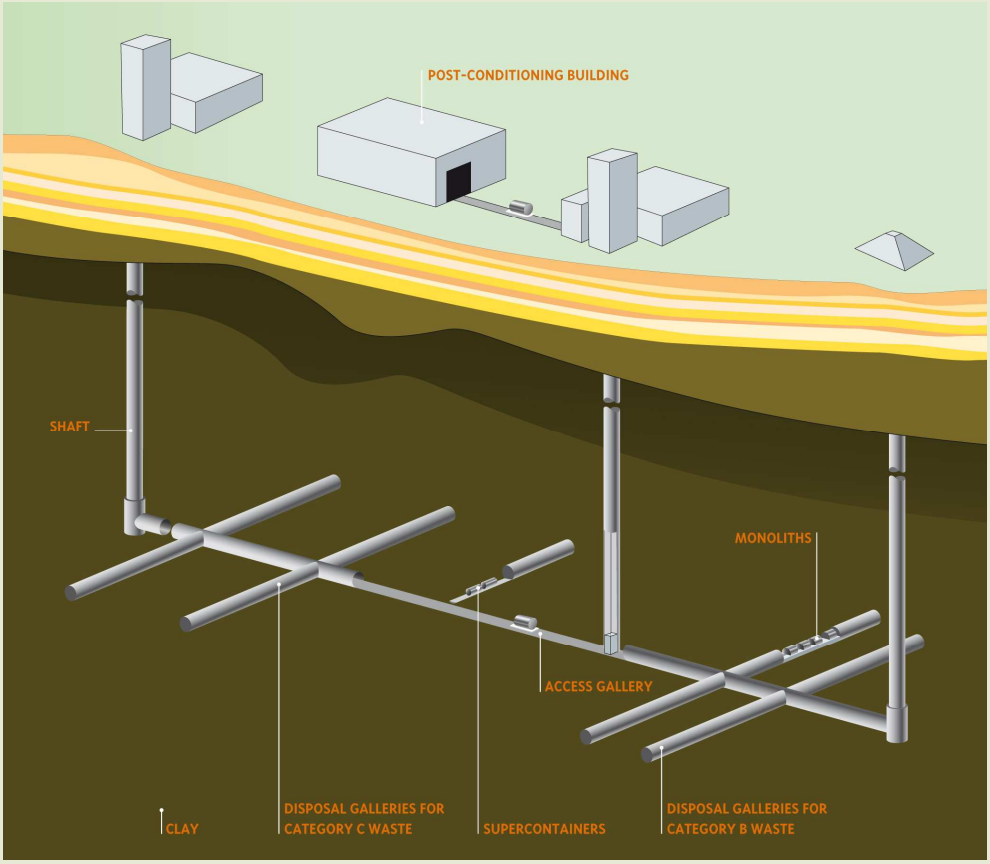

Figure 3 – Indicative diagram of the geological repository envisaged for B&C waste and of the surface facilities for the production of supercontainers and monoliths.

The solution of geological disposal in poorly indurated clay is flexible enough to adapt to the additional conditions to which its implementation could be subjected, such as those discussed in section 4.3, and to the potential variations identified in B&C waste volumes to be managed (section 5.1).

The latest estimate of the non-discounted total cost, including margins for technological and project risks, of geological disposal in Boom Clay at a depth of approximately 220 metres, in the event of a full reprocessing of all commercial fuel, amounts to some EUR_{2008} 3 billion.

Long-term safety assessments

The impact of the repository in the long term was assessed on the basis of the considerable knowledge and expertise available both at national and international level.

The uncertainties about the evolution of the disposal system were analysed by taking them into account in a reasoned manner in a range of scenarios. This range includes the reference scenario, which describes the expected evolution of the disposal system, and its variants, a number of other evolution scenarios that are possible but less probable (substantial rise in sea level, seisms, glaciation, early failure of the engineered barriers,...), and human intrusion scenarios.

The main achievements concerning the assessment of long-term safety under normal conditions were gathered for a repository supposed to be built in the middle of the 100 metre thick layer of Boom Clay in the region of Mol–Dessel. They are based on cautious (sometimes even pessimistic) assumptions that amount to introducing significant safety margins into the results obtained. They can be summarized as follows.

- Boom Clay is the main contributor to long-term safety.
- Engineered barriers make an effective contribution to long-term safety that largely exceeds requirements.
- Waste matrixes play a minor part in long-term safety, except for the UO_2 matrix of nuclear fuel.
- The maximum dose generated by the repository is at least 10 times lower than the regulatory limit:
  - the main contributors to the dose are the fission products which are not retained in the Boom Clay (^{129}I, ^{36}Cl, ^{14}C,...),
  - actinides (U, Pu, Am, Cm and Np) make only a very small contribution to the dose,
  - most radionuclides decay to insignificant levels during their stay within the engineered barriers and their transport through the Boom Clay.
- The most mobile fission products leave the Boom Clay after some tens of millennia; actinides leave the Boom Clay after several hundred thousand years. In both cases, the quantities are negligible.
- The presence of a geological repository in the Boom Clay has no negative impact on the aquifers on either side of the Boom Clay and does not preclude their exploitation as a source of drinking water.

The assessment of the other possible evolution scenarios and of the human intrusion scenarios does not result in conclusions that differ considerably from those obtained for the reference scenario.

In general, the long-term safety assessment results are coherent with the results obtained within the scope of the other national programmes in the field of geological disposal, which enhances the confidence in these assessments.

The presence of water-bearing formations on either side of the Boom Clay and the Ypresian Clays is of particular importance for ONDRAF/NIRAS, with respect to their radiological protection, the limitation of physicochemical perturbations (thermal impact, presence of chemical toxic elements,...) and the risk of human intrusion.

It is of course up to FANC and the authorities competent to deal with environment protection to assess, during the licence application process with a view to geological

disposal, the degree of safety and protection ensured by the disposal system developed and to authorize its implementation.

Feasibility assessments

The construction of the underground research laboratory HADES, in particular the last extension phase, showed it is possible to industrially build shafts and galleries in the Boom Clay at a depth of more than 200 metres while limiting the geomechanical perturbations of the clay. Besides, the large-scale demonstration experiments confirmed the possibility of different operation types, for instance the backfilling of the disposal galleries, the sealing of the shafts and the handling of the supercontainers and monoliths in shafts and galleries according to known industrial methods. These achievements have been confirmed in other countries.

Peer reviews

Scientific and technical achievements in the field of disposal in poorly indurated clay, in particular 30 years of RD&D in the underground laboratory HADES, were assessed several times by Belgian and international experts. Their conclusions can be summarized as follows.

- The findings are based on solid scientific grounds and have reached a sufficient degree of maturity in order to render a favourable opinion on the safety and feasibility of this solution. Ongoing research in other countries confirms the potential of clay formations for confining disposed waste and retaining radionuclides and chemical contaminants.
- The remaining uncertainties are systematically analysed and taken into account in the safety and feasibility assessments, which show that these uncertainties do not undermine the safety and/or feasibility of this solution. Reducing uncertainties is the main objective of ongoing and future RD&D programmes.

Moreover, the validity of activities with regard to disposal in poorly indurated clay has been confirmed several times by different Belgian commissions and working groups asked by institutional bodies to give their opinion on problems including — to varying degrees — the radioactive waste management issue.

Maturity of the technical solution and decision in principle

According to ONDRAF/NIRAS, none of the reasons that might prompt to delay a decision in principle supporting geological disposal in poorly indurated clay is justified: this solution is *technically mature enough to be the object of a decision in principle,* since the uncertainties that still have to be lifted are not considered prohibitive. Besides, making such a decision now does not rule out the possibility of continuing RD&D in order to develop a geological disposal solution and to prepare its implementation. Quite the opposite in fact, it is essential and planned: continuing RD&D will progressively enable confirming and refining the achievements so as to increase safety margins, reduce remaining uncertainties and optimize the disposal system. Protection of the aquifers on either side of the Boom Clay and of the Ypresian Clays will be one of the focal points.

Nor does a decision in principle supporting geological disposal in poorly indurated clay rule out the feasibility of following up evolutions in terms of management possibilities that were examined in the Waste Plan but were discarded. Besides, in its opinion on the draft Waste Plan and the SEA, FANC confirms that surface disposal, *"be it pending the development of new techniques or for a period of several centuries"* [translation ONDRAF/NIRAS], cannot be justified.

Opting for geological disposal in poorly indurated clay as a solution for the long-term management of B&C waste de facto limits the area of the Belgian territory where a repository could be located in the north-east and the northernmost point in the west of Belgium. However, this choice does not imply the immediate choice of a construction site.

4.1.3 In a single facility

According to ONDRAF/NIRAS, category B and category C wastes must be managed in the long term within the scope of a management solution — geological disposal — which, on the one hand, is common to both types of waste since the risk they pose in the long term stretches over similar time scales, i.e. several tens or hundreds of millennia, and, on the other hand, is implemented on a single site, since their respective volumes are such that different facilities cannot reasonably be envisaged from an economic point a view. Geological disposal will, however, be designed and operated in such a way that waste with different properties will be placed sequentially and in different sections of the repository.

4.1.4 On Belgian territory

ONDRAF/NIRAS considers that B&C waste (as well as the other waste for which it bears responsibility) must be managed within a national framework, and therefore on Belgian territory. Since Belgium decided in the sixties to use nuclear energy to produce an important part of its electricity, and since the major part of Belgian radioactive waste originates from the whole nuclear fuel cycle, it is actually up to Belgium to ensure the management of its radioactive waste, regardless of its future energy policy. This position is in line with the recommendations and regulations in force at the international level, which emphasize the responsibility of each country for the management of its own radioactive waste.

4.1.5 As soon as possible

Geological disposal ought to start as soon as possible, in light of the scientific, technical, societal and regulatory constraints to be taken into account. In other words, the pace of development and implementation of the disposal solution will have to be proportionate to its scientific and technical maturity, as well as to the public support it receives: the programme dynamics will have to be maintained, however, without taking any shortcuts.

Implementing geological disposal as soon as possible aims at

- enabling ONDRAF/NIRAS to have a complete management system for B&C waste, which can be optimally organised, and thus to fulfil its assignment;
- enabling ONDRAF/NIRAS to assess the effective cost of disposal, and hence to apply the "polluter pays" principle on a concrete basis;
- ensuring the maintenance of expertise and know-how at national level, in particular in the fields of waste knowledge, RD&D and assessment of disposal system performances, which makes an essential contribution to safety;
- minimizing the burdens transferred to future generations and lifting the uncertainty for the municipalities on whose territory the waste is currently stored, for a temporary, yet indefinite, period of time.

Since the development and implementation of a global geological disposal solution integrate scientific, technical, decision-making and societal aspects, the timing of the development and implementation programme cannot be established a priori, but will instead be determined gradually by a number of factors (RD&D evolution and results, building and maintenance of public support, siting process, content of the decisions made in the course of the decision-making process,...).

From a strictly technical and voluntaristic point of view, in light of the current knowledge, geological disposal of the first waste, which will be category B waste, a priori cannot be envisaged before 2035–2040: it will take at least another fifteen years to implement the necessary participative processes, to refine, confirm and optimize the recommended solution by means of RD&D activities, to strengthen societal support, especially through the siting process, and then to prepare and submit the licence applications and obtain the necessary licences, in particular the nuclear licence for "construction and operation" which is needed to start building the repository. It would take about fifteen years to build the repository.

4.2 Decision-making process

The development and implementation of the recommended technical solution fit into a decision-making process that integrates technical and societal aspects. ONDRAF/NIRAS wishes this process to advance in steps, to be adaptable, participative and transparent, and to ensure continuity. It will run for approximately one hundred years from the moment a decision in principle is made, since decisions will have to be made at least until the closure of the repository.

ONDRAF/NIRAS drafted a first outline of decision-making process, which will serve as a basis for discussion, to be improved, refined or even modified through dialogue with all of the stakeholders. This dialogue, which ONDRAF/NIRAS intends to launch in the very near future, will start by identifying the stakeholders that will be taking part in the decision-making process. The dialogue process should help determine who will decide what, when, on what basis and how. Actually, with the exception of the provisions of the law of 13 February 2006, there currently exists no normative system describing how to complete the different steps between a decision in principle on the long-term management of radioactive waste and the nuclear licence application needed to implement the management solution chosen. Identification of the key decisions to be

made, of the stakeholders taking part in the different steps of the decision-making process, of the respective roles and responsibilities or, for instance, of the documentation to be prepared, presents a major challenge. Dialogue, the financing of which also has to be organised, will allow integrating the participative dynamics into the B&C programme, which up until a few years ago largely ignored this dimension.

The decision-making process should be included in the normative system to be established, which will have to provide ONDRAF/NIRAS and all stakeholders with whom it will cooperate, with a sufficiently stable and well defined framework for the development and implementation of the recommended technical solution.

The normative system to be established should include the creation of an independent monitoring body entrusted with the responsibility of ensuring that the decision-making process advances in completely documented steps, that it is adaptable, participative and transparent, and ensures continuity and integration of the societal and technical aspects.

4.3 Conditions arising from the consultations

ONDRAF/NIRAS considers that the development and implementation of the technical solution it recommends will have to meet, in addition to the applicable standards and regulations, conditions arising from the consultations. These conditions result from concerns that are largely shared by the public and from concerns expressed by the official institutions consulted. Some of these conditions pertain to the development and implementation of a solution for the long-term management of radioactive waste and have been transposed by ONDRAF/NIRAS to the specific case of geological disposal (section 4.3.1), while other conditions have to do with the need to follow up developments regarding management possibilities that were examined but were discarded in the Waste Plan (section 4.3.2).

Other societal concerns, in particular the need for independent monitoring of the decision-making process, were included in the technical solution and/or the decision-making process outlined by ONDRAF/NIRAS (section 4.2).

4.3.1 Conditions linked to the development and implementation of the recommended technical solution

In general, the public, whether or not it is in favour of a geological disposal solution, considers that it must be possible to retrieve the radioactive waste from the facility in which it has been placed, that it must be possible to control that the facility is functioning properly and is safe, and that the knowledge as regards both the waste and the facility must be passed on from one generation to the next.

ONDRAF/NIRAS intends to take account of these demands in developing and implementing the geological disposal solution it recommends. *The scope of these demands will have to be further determined in dialogue with all of the stakeholders, taking into account the need to meet the requirements regarding safety and technical and financial feasibility.*

In this context, ONDRAF/NIRAS undertakes to:

- ensure the reversibility of the disposal during operation and examine the measures that could facilitate the possible retrieval of the waste after partial or complete closure of the disposal facility for a period that is yet to be defined. However, enhancing retrievability in the design and implementation of a disposal facility cannot occur at the expense of radiological safety, physical security and non-proliferation measures for nuclear materials (*safeguards*); it could have an impact on the cost of the disposal facility;
- continue the controls of the repository's functioning which will be performed in addition to regulatory controls for a period that still has to be agreed upon with the stakeholders. However, these controls cannot be performed at the expense of perturbations of the system and thus of its proper functioning;
- prepare in the most appropriate way the transfer of knowledge of the repository and the waste it contains to future generations. This transfer can be organised both at national and international level, in particular by means of the reports to be provided under international requirements. However, it is up to each generation to determine what knowledge and resources it wishes to pass on to the next generation.

4.3.2 Follow-up conditions

Parallel to the development and implementation of the geological disposal solution it recommends, ONDRAF/NIRAS will continue to follow up developments regarding management possibilities that were examined but were discarded in the Waste Plan. So it will continue to

- follow up the evolution of the knowledge on schistose formations as such and as possible host formations, in order to maintain a fallback solution on Belgian territory if the poorly indurated clays are eventually rejected;
- follow up the evolution of the knowledge on disposal in deep boreholes, in order to have, if needed, a solution for the long-term management of very limited quantities of waste, the retrieval of which we would like to make particularly difficult;
- follow up, through international institutions, the evolutions in the development of geological repositories shared by several EU Member States, in order to apprehend policies in this matter and their possible impact on the Belgian programme;
- follow up national and international developments in the field of advanced nuclear technologies, although these technologies will not make any contribution to the long-term management of existing and planned conditioned waste. This follow up is justified by the fact that, on the one hand, the policy for the management of commercial used fuel from the current nuclear park has not yet been determined and, on the other hand, the research facilities dedicated to advanced nuclear technologies will themselves generate waste that will have to be managed in the long term.

5 Proposals and recommendations on related issues the answers to which are not a matter solely for ONDRAF/NIRAS

Various issues the answers to which are not a matter solely for ONDRAF/NIRAS impact or will impact on its management activities. They can be divided into two groups: issues relating to the long-term management of B&C waste, and issues concerning the development of one or more additional management systems. They are the subject of different proposals and recommendations.

5.1 Long-term management of B&C waste

In order to be able to fulfil its assignment related to B&C waste management, ONDRAF/NIRAS must not only have confirmation of the solution it recommends for the long-term management of this waste, but it must also

- have a regulatory framework in place which is sufficiently clear and exhaustive for the geological disposal of B&C waste;
- be able to anticipate in due time any variations in the volumes and types of B&C waste to be disposed of.

These issues are not a matter solely for ONDRAF/NIRAS.

As a result,

- *as far as the specific regulatory framework for geological disposal of B&C waste is concerned,*
  - ONDRAF/NIRAS would like this framework, which is currently being developed by FANC, to be available as soon as possible;
- *as far as the capacity of anticipating in due time any variations in the volumes and types of B&C waste to be disposed of is concerned,*
  - ONDRAF/NIRAS recommends that the status (resource or waste) of used nuclear fuel from commercial reactors be clarified;
  - ONDRAF/NIRAS recommends that the status (resource or waste) of the enriched fissile materials and plutonium-bearing materials excluding fuel held by some operators be clarified;
  - ONDRAF/NIRAS recommends that its opinion be sought in due time by the competent authorities in all dossiers in which decisions likely to have a significant impact on radioactive waste management (for instance opting for the reprocessing of used fuel, increasing the fuel burnup, designing a new major nuclear facility, remediating a radioactively contaminated site) must be made.

However, the fact that a specific regulatory framework for geological disposal of B&C waste is not yet available, and the uncertainties about possible variations in the volumes and types of B&C waste to be disposed of through geological disposal do not eliminate the need for a decision in principle and the possibility to make this decision.

5.2 Development of one or more additional management systems, in particular for radium-bearing waste

Since ONDRAF/NIRAS must ensure the long-term management of all radioactive waste that exists on Belgian territory, it intends to be prepared for addressing different issues concerning substances that currently do not have radioactive waste status but could acquire it later on. These issues concern existing situations for which radiological remediation decisions were made or are likely to be made by FANC. It also intends to be prepared for coping with the issue of long-term management of radioactive waste contained in licensed interim storage facilities for which no application has been submitted yet in order for ONDRAF/NIRAS to take charge thereof. These different issues essentially concern radium-bearing waste and waste from certain sectors of the non-nuclear industry — for instance the phosphate industry and the cement industry — which deal with naturally radioactive raw materials without the radioactive character being a desired property of these substances ("NORM" and "TENORM" waste).

The long-term management of radioactive waste resulting from future remediations and of radioactive waste contained in the licensed interim storage facilities will prompt ONDRAF/NIRAS to develop one or more management systems complementary to the existing system. Actually, these wastes are all long-lived radioactive waste, mainly very low-level and low-level, spread across numerous sites, and represent potentially significant volumes.

In concrete terms, ONDRAF/NIRAS will in the coming years draw up a plan on the long-term management of radium-bearing waste that exists on Umicore's site in Olen and in the surrounding area, as well as of radium-bearing waste already in its storage facilities. This plan will aim at proposing a long-term management policy for this waste, which will provide the necessary framework for its optimal management, taking account of its specific characteristics. In order to develop a comprehensive plan, ONDRAF/NIRAS will, however, have to be informed by FANC about the general principles applicable to the long-term management of radium-bearing waste and to know in due time its position as to whether or not it is necessary to remediate the different landfill sites and grounds in Olen for which a decision is currently pending.

Moreover, if FANC decides that some other situations (situations pertaining to the NORM and TENORM issue or regarding the existence of old diffuse radioactive pollution on certain grounds) must be radiologically remediated, ONDRAF/NIRAS will examine the issue of these remediations in consultation with FANC, within the scope of a new management plan as the case may be.

The prospect of a plan on the long-term management of radium-bearing waste and, if need be, of one or more subsequent plans does not question the considerations and findings concerning category B and category C wastes developed in the Waste Plan: this existing and planned waste can be managed in the long term within the scope of the global solution recommended by ONDRAF/NIRAS.

6 Waste Plan implementation

Commencement of the implementation of the Waste Plan, which was adopted by the Board of Directors of ONDRAF/NIRAS on 23 September 2011, must be validated by a

decision in principle from the Federal Government establishing a clear policy for the long-term management of B&C waste. This implementation will include a series of actions enabling the practical realisation of the long-term management solution chosen, such as the choice of a host formation, the choice of possible construction areas, the formalizing of societal consultation processes and structures, the choice of one or more construction sites, the local integration of the solution and the licence applications. The gradual development of this management policy will require the introduction of an appropriate normative system, which is currently lacking.

7 Link with the European "Waste" Directive of 19 July 2011

The global solution recommended in the Waste Plan for the long-term management of B&C waste, if validated by a decision in principle, will contribute to fulfilling several requirements of the European "Waste" Directive of 19 July 2011 establishing a community framework for the responsible and safe management of spent fuel and radioactive waste. This solution is actually in line with the principles of the Directive, in particular the national responsibility for waste management, the fact that the safety of this management in the long term requires a facility that passively ensures safety, the "polluter pays" principle, the intergenerational equity principle, which requires current generations to avoid transferring undue burdens to the future generations, and the establishment of a documented and participative decision-making process. It represents the solution which the Directive considers to be *"the safest and most sustainable option as the end point of the management of high-level waste and spent fuel considered as waste"*.

The Waste Plan as such serves as a preparatory document for the first Belgian national programme, which will have to be notified to the Commission by 23 August 2015 at the latest and will have to cover all stages of the management of used fuel and radioactive waste.

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