

The Belgian Research and Development Feasibility Programme for the Geological Disposal of High-Level and Long-Lived Radioactive Waste - 12338

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ABSTRACT

ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials, considers geological disposal in the poorly indurated Boom Clay as the reference solution for the long-term management of high-level and/or long-lived radioactive waste. To develop a safety concept and design for geological disposal, ONDRAF/NIRAS follows an iterative process demonstrating that the repository will be both safe and feasible to implement. This process is called the safety strategy.

A part of the safety strategy is the feasibility programme which aims at demonstrating, at a conceptual level, that the proposed geological disposal system can be constructed, operated and progressively closed. The followed methodology is based on the substantiation of a hierarchy of feasibility statements. These statements cover all activities from the removal of primary waste packages from interim storage buildings to the closure of the disposal site and a period of institutional control. They focus on engineering practicability, health & safety and environmental considerations, costs and quality assurance issues.

A 4 year research project to support the R&D feasibility programme was launched in 2009 with several international partners coordinated by ONDRAF/NIRAS. It aims at confirming that there are no fundamental flaws or showstoppers in the feasibility of building and operating the facilities for geological disposal in the Boom Clay.

INTRODUCTION

The reference solution for the long-term management of high-level and/or long-lived radioactive waste as currently considered by ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials, is geological disposal in the poorly indurated Boom Clay. The current concept of geological disposal is described in the Waste Plan that ONDRAF/NIRAS submitted to the Belgian government in 2011 [1]. The Waste Plan should lead to a confirmation of geological disposal as the reference concept for the long-term management of category B and C wastes¹.

¹ Belgian high-level and/or long-lived radioactive waste is classified as category B and C waste. Category B waste has a low or medium activity level (contact dose rate < 3 Sieverts per hourn(Sv/h)) and is made up of radioelements of which the majority has a life span of more than 30 years. Category C waste has a high activity level (contact dose rate > 3 Sv/h). Because of the high activity level, most category C waste emits considerable amounts of heat (more than 20 Watt per cubic metre).

To guide the development of a safety concept for geological disposal and a repository design in the Boom Clay, ONDRAF/NIRAS follows an iterative process, called the safety strategy [2]. The safety strategy guides, firstly, the stepwise development of a safe and feasible geological repository and its implementation procedures and, secondly, the successive license applications. An integral part of this safety strategy is the feasibility strategy as the proposed disposal system also has to be feasible to implement [3].

An important component in the safety and feasibility strategy is the development of a safety and feasibility case (SFC). The SFC integrates scientific and technological arguments and evidence that, at the given stage of development, describe, substantiate and, where possible, quantifies the safety and feasibility of the proposed disposal system. It furthermore identifies remaining uncertainties or open issue in the repository development and provides guidance to resolve these issues in future development stages.

ONDRAF/NIRAS currently prepares for the submission of a first SFC-1 in 2014. The SFC-1 follows the earlier mentioned Waste Plan and should support a subsequent decision to “go-for-siting” (Fig. 1).

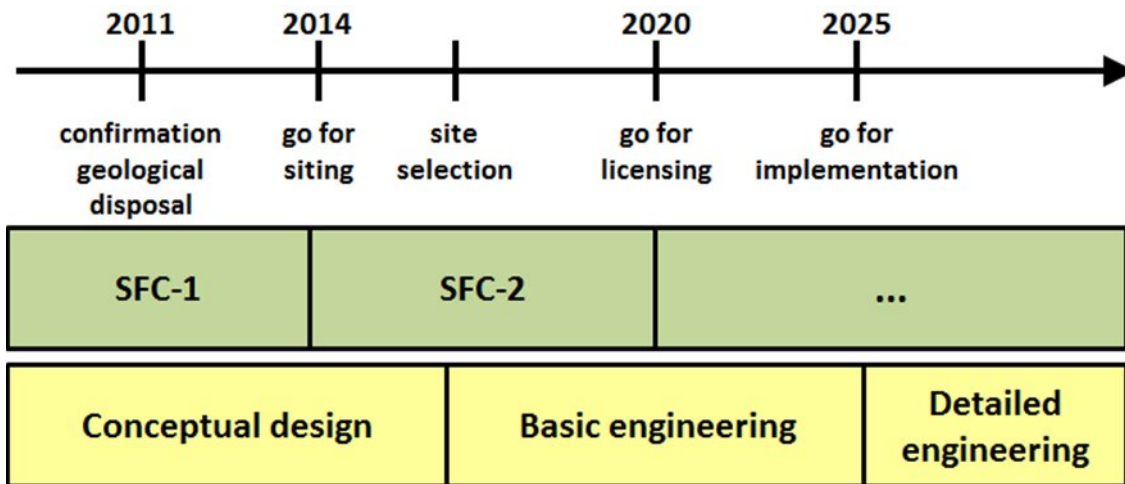


Fig. 1 Expected schedule for the development of a geological repository and the disposal of category B&C waste in Belgium

SAFETY STRATEGY

The safety strategy is the methodology ONDRAF/NIRAS follows to develop the safety concept and design for geological disposal. The safety strategy has to demonstrate that the disposal system for category B and C waste meets its safety objective. According to the International Atomic Energy Agency (IAEA), the fundamental safety objective of all radioactive waste management activities is the protection of people and environment from the harmful effects of ionizing radiation [4,5]. For high-level and low- and intermediate long-lived waste (i.e. category B and C wastes), the current internationally recommended solution is disposal in a stable

geological formation. This solution is based on a strategy of concentration and containment of the radionuclides and other contaminants.

The development of a safety concept and a repository design is based on several design principles and has to take into account several boundary conditions.

Design Principles

Based on a review of international practices, the following safety design concepts have been defined and will underpin the development and implementation of a geological repository for radioactive waste:

- Isolation and containment;
- Passive safety;
- Defence in depth;
- Radiation protection;
- Best available and proven technologies (BAT); and
- Enhancing confidence in safety.

Isolation and containment of the radionuclides, after closure of the repository, entail the confinement and isolation of radionuclides from the biosphere for as long as reasonably possible. This ensures that the radiological consequences when the radionuclides eventually migrate out of the repository and arrive in the biosphere, remain within acceptable limits. In practice this means that the radionuclides are immobilized and the waste is kept isolated from flowing groundwater. Isolation means that the waste is placed in an environment such that that the risk of direct contact with humans is minimized.

The requirement for passive safety is defined by the IAEA as follows: "The operator shall site, design, construct, operate and close the geological disposal facility in such a way that safety is ensured by passive means, and does not depend on actions being taken after closure of the facility" [5]. Long-term safety must thus be ensured by the characteristics of the radioactive waste and by the engineered and natural barriers, and must not rely on human actions taken after closure of the facility.

The principle of defence in depth implies a disposal site and a disposal concept involving multiple safety barriers and long-term safety functions. The existence of multiple safety functions provided by a range of physical and chemical phenomena contributes to the robustness of the disposal system. It also helps to mitigate the effects of potential uncertainties on the overall performance of the disposal system. The adequacy of the application of the defence in depth principle is judged by safety assessment of the system as a whole.

Radiation protection involves keeping radiological exposure of present and future human generations as low as reasonably achievable (the ALARA principle). This principle is realized by:

1. Justification of the exposure or the net benefit must be positive. For disposal this benefit is the necessity of no longer having to operate surface storage facilities.
2. Optimization of protection. The means of protection must be chosen in such a way that the individual doses and the number of people exposed are kept at as low a level as is reasonably possible, taking into account economic and social factors, operational issues and long-term impacts.
3. Limitation of risks to individuals, firstly by limiting the external radiation dose of the waste and if necessary using shielding, and secondly by limiting the occupational time that is spent close to the radiation source presented by the waste.

The principle of Best Available Technology (BAT) will, in particular, guide the selection of materials that play a long-term safety role. Application of the BAT principle in designing the repository, leads to preferences for materials and procedures for which broad experience and knowledge already exists. The construction and operation technologies must have a proven effectiveness and be as simple as possible, since greater complexity will increase the risk of failure. For the same reason, the materials used should be simple and well known, and should be available in the future, thereby allowing robust assessment of the behavior of the material and its interactions.

Finally enhancing confidence in safety is achieved by adopting the following approaches:

- Developing an adequate understanding of the safety functions and performance of key barriers in the repository, and relying on behavior that can be verified through initial tests, current understanding or continuous/periodic monitoring;
- Providing convincing evidences to demonstrate safety;
- Improving safety through experience, feedback, focused safety assessments and independent reviews; and
- Building confidence in safety through monitoring and surveillance.

Boundary Conditions

The repository design and the assessment of its safety and feasibility must take account of various boundary conditions. These are:

- Scientific basis for the reference design;
- International and Belgian frameworks;
- Institutional policy and conditions required by other stakeholders; and
- Strategic choices by ONDRAF/NIRAS.

A first set of boundary conditions results from the scientific basis for the reference design that is developed by previous R&D programmes. These research programmes demonstrated that poorly indurated clay could provide a safe host rock for geological disposal, and that the natural barrier (the Boom Clay) would be a major contributor to safety for both the reference evolution scenario and for most altered evolution scenarios.

Other boundary conditions are the international and Belgian frameworks. The international framework is mainly provided by the IAEA [4,5], the ICRP [6,7,8,9] and the European Union. It also includes relevant guidance observed in other industries. The Belgian legal and regulatory framework includes legislation that is applicable to the operational safety of a geological repository such as legislation on conventional safety at work, nuclear safety, safety in mines and underground facilities and protection of the environment.

The institutional policy and conditions required by other stakeholders includes recommendations made by competent authorities that are not incorporated into the legal and regulatory framework, such as the Belgian nuclear regulatory agency, the FANC. These boundary conditions also include the preferences of stakeholders and their representatives.

Finally, a number of strategic choices have already been made by ONDRAF/NIRAS [2]. The strategic choices are working hypotheses that are, in the absence of decisions at the institutional level, necessary to manage the geological disposal programme in a focused way. The strategic choices are:

1. The repository will be constructed in the Boom Clay formation. The Ypresian Clays are considered as alternative host formations.
2. The materials and implementation procedures will not unduly perturb the inherent safety functions of the host formation or of any other component.
3. In the case of heat-generating waste, the engineered barriers will be designed to provide complete containment of the wastes and associated contaminants at least through the thermal phase.
4. Waste types will be divided into groups to be emplaced in separate sections of the repository.
5. Repository construction and operation will proceed as soon as possible, but taking due account of scientific, technological, societal and economic considerations.
6. The different disposal galleries and repository sections, and the repository as a whole, will be closed as soon as practically possible following emplacement of the wastes.
7. There are preferences for permanent shielding of the wastes and for minimization of operations in the underground.
8. There are preferences for materials and implementation procedures for which broad experience and knowledge already exists.
9. Repository planning will assume that post-closure surveillance and monitoring will continue for as long as reasonably possible.

FEASIBILITY STRATEGY

Part of the safety strategy is the feasibility strategy as the safety objective can only be achieved if the proposed disposal is feasible to implement [3]. The feasibility strategy aims at demonstrating that the proposed conceptual design can be constructed, operated and progressively closed. The followed methodology is based on the substantiation of a hierarchy of

feasibility statements. The feasibility statements are organized in a tree structure (Fig. 2) with the top-level feasibility statement being the main objective of the feasibility assessment. The top-level feasibility statement is defined as: “The proposed disposal system can be safely constructed, operated and progressively closed, taking into account long-term safety requirements and operational safety requirements, at a cost that is commensurate with available funding”. This general statement is underpinned by 4 other statements: engineering practicality, operational safety, cost and quality procedures.

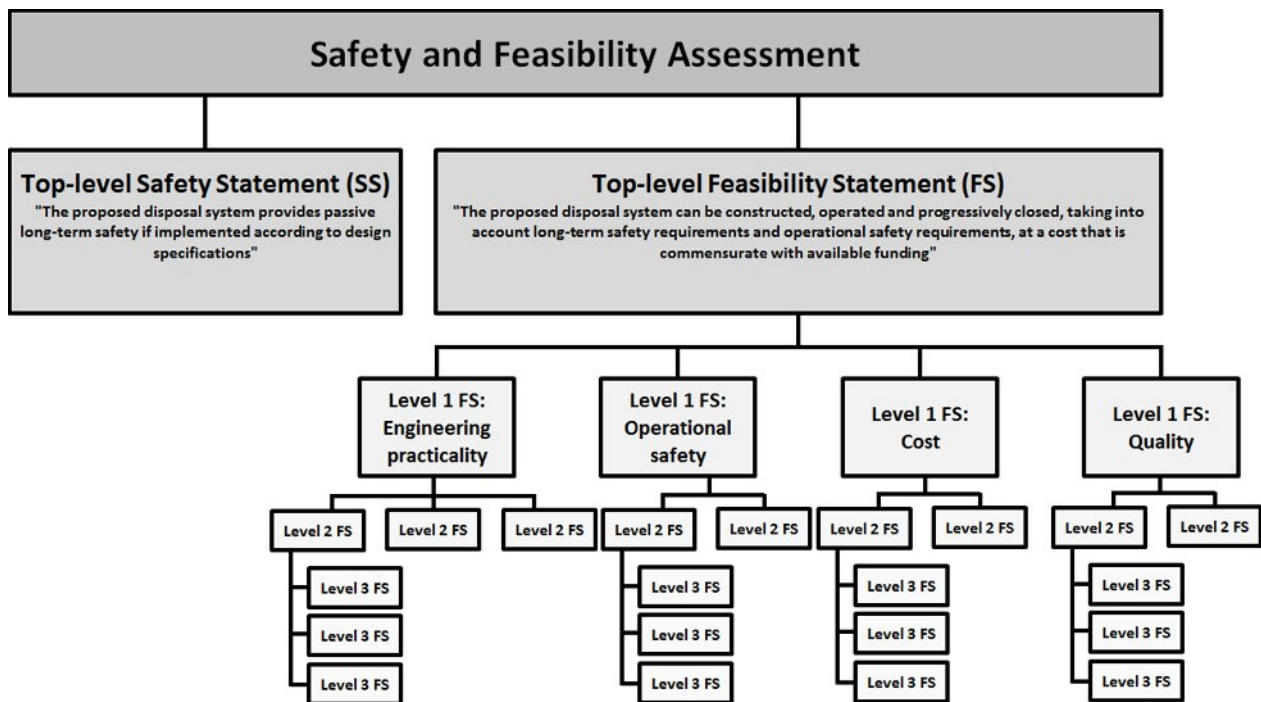


Fig. 2 Structure of the Feasibility Statements

Lower-level feasibility statements relating to the different components of the disposal system are then derived from these top-level feasibility statements and defined using a top-down approach. Substantiation of the feasibility statements is performed in a bottom-up fashion.

The feasibility statements cover all activities from the removal of primary waste packages from interim storage buildings to the closure of the disposal site and a subsequent period of institutional control. A comparable set of safety statements has also been developed to substantiate and demonstrate the safety of the disposal system.

Currently, a research project is ongoing to support the R&D feasibility programme [10]. It aims at confirming that there are no fundamental flaws or showstoppers in the feasibility of building and operating the facilities needed for geological disposal in the Boom Clay. The project has to:

- Review the current state of knowledge and understanding relating to each feasibility statement;

- Identify the open questions that need to be addressed to demonstrate that every step in the waste category B&C disposal concept is feasible; and
- Undertake R&D studies to address the remaining open questions and to provide sufficient evidence underpinning the feasibility for SFC-1.

The studies of the research project are subdivided into following topics:

- Fabrication of the waste disposal packages;
- Construction of the underground repository; and
- Operation of the underground repository.

The ongoing R&D activities on the underground repository layout and construction and on the operation of the underground repository are presented in companion papers to the present paper. These companion papers are also presented at WM2012 Conference [11;12].

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