Methodological Safety Case for the Belgian Geological disposal facility for category B&C waste

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Summary

For more than 40 years, ONDRAF/NIRAS (the federal agency responsible for managing radioactive waste and enriched fissile materials in Belgium) has been studying geological disposal in poorly indurated clays as an option for the long-term management of category B waste (low-level and intermediate-level long-lived waste – LLW-LL) and category C waste (high-level waste – HLW and spent fuel). In the absence of a political decision regarding the management of category B and C waste, a geological disposal facility (GDF) in poorly indurated clays is still the current reference option considered for the Research, Development and Demonstration (RD&D) programme.

The RD&D programme for the geological disposal for category B&C waste has been implemented in a cautious, stepwise process, punctuated by the production of key documents such as the SAFIR & SAFIR-2 reports in 1989 and 2001, the waste Plan in 2011 and the RD&D Plan in 2013. In the future, in line with international practices, ONDRAF/NIRAS will produce Safety and Feasibility Cases (SFCs). The first SFC will be a methodological safety and feasibility case (SFC-1). This SFC will aim to test the methodological tools that have been developed, and illustrate the safety and feasibility of a GDF for category B&C waste in poorly indurated clays at a depth between 200 m and 600 m.

The paper presents the approach developed at ONDRAF/NIRAS to establish the SFC methodology (e.g. generic sites, generic design), the structure of the SFC and some methodological tools.

Introduction

In the absence of a political decision regarding the management of category B and C waste, geological disposal in poorly indurated clays is still the current reference option considered for Research, Development and Demonstration (RD&D) in Belgium. This option implies either the Boom Clay or the Ypresian clays as a reference host rock. These clays are present in continuous layers in the north of Belgium up to a depth of about 600 m. Therefore, the proposed reference option for the management of category B and C waste is a geological disposal facility (GDF) in poorly indurated clays at a depth of between 200 and 600 m.

The RD&D programme for the GDF for category B&C waste has been implemented in a cautious, stepwise process, punctuated by the production of key documents:

- In 1989, the existing scientific and technical research on disposal in Boom Clay was summarised in a Safety Assessment and Feasibility Interim Report (SAFIR)
• In 2001, SAFIR-2 was presented summarising the RD&D studies in the period 1990-2001. SAFIR-2 and its national (Board of Governors) and international (Nuclear Energy Agency) peer reviews confirmed that the proposed solution for disposal in Boom Clay was promising and that no major flaws in the proposed concept were identified. However, in the SAFIR-2 assessment, the safety methodology, the management of uncertainties, the operational safety issues, the consideration of category B waste, and the understanding of the behaviour of the Engineered Barrier System (EBS) were limited.

• In 2011, the Waste Plan with its accompanying strategic environmental assessment (SEA) was submitted to the Belgian federal government. This report compared different possible options for long-term management (including geological disposal, perpetual storage, partitioning and transmutation, ...) and was intended to lead to a decision-in-principle (i.e. policy according to EC directive 2011/70/Euratom) regarding the type of solution to be implemented for the long-term management of category B&C waste.

• In 2013 the RD&D Plan was published. It presents the status of knowledge regarding the development of geological disposal of category B&C waste in poorly indurated clays.

Objective of the SFC-1

In the future, in line with international practice, ONDRAF/NIRAS will produce Safety and Feasibility Cases (SFCs) for the management option that will be selected in Belgium. Assuming that the policy for long-term management of category B and C waste will be that proposed by ONDRAF/NIRAS, i.e. geological disposal, the SFCs that are expected in the coming decades are:

• A methodological SFC (SFC-1)
  o to synthesise the scientific knowledge acquired since the start of the GDF program in Belgium
  o to test the safety assessment methodology and methodological tools developed at ONDRAF/NIRAS, through an illustrative assessment of the safety and feasibility of a GDF in poorly indurated clays (generic sites) based on current knowledge, considering an updated reference repository design and using safety assessment models developed by ONDRAF/NIRAS

• One or several SFC(s) to confirm the safety and the feasibility for specific sites.

Within the framework of the first, methodological SFC, SFC-1, the reference design of the Belgian GDF is conceptual and without any presumption about the exact location of the facility. This SFC considers a broad region in the North of Belgium where Boom Clay and Ypresian Clays are present at different depths and in various geological configurations. Generic geological sites will be analysed in SFC-1. They cover the different types of geological configuration in the region of investigation. The main features distinguishing these generic sites are the depth of the host layer, and the structure of associated aquitards and aquifers, with different assumptions regarding their hydraulic properties. These features of the geological environment are the most relevant in terms of engineering feasibility and long-term safety.

In absence of political decision, and legal framework, this generic approach is preferred to an in-depth study of specific RD&D sites. A generic approach is sufficient at this stage of the programme to test methodological tools and to guide future RD&D. This generic methodology allows the minimum requirements for the safe and feasible disposal of category B and C waste in poorly indurated clays to be identified (as well as the interdependencies between these requirements). Providing generic criteria, separately
from the specific characteristics of a particular RD&D site, allows an iterative process to be followed towards choice of a specific site, including interaction with regulators and the public.

**Reference design for SFC-1**

The reference option for radioactive waste disposal foresees conditioning in dedicated surface facilities of category B and category C wastes in disposal packages, respectively called the Monolith B and the supercontainer. The Monolith B and the supercontainer will then be emplaced in the GDF. The reference option design results from an update of the GDF layout dating to 2003. The current layout takes into account the range of depth (200 to 600 m), and considers results from a preliminary optimisation of GDF operational safety. It also integrates the update of the reference programmes (waste inventory) of the waste producers. The GDF will be constructed, operated and closed during two distinct periods (with no overlap between these periods). In a first step, the GDF for category B waste will be constructed, operated and eventually closed. In a second step, the GDF for category C waste will be constructed, operated and eventually closed. The conceptual development of the GDF for category B and C wastes is illustrated in Figure 1.

**Figure 1: SFC-1 GDF reference layout**

The structure of the SFC-1 Safety Case

SFC-1 will consist of one self-supporting report illustrating the application of the safety assessment methodology to a GDF for category B and C waste in poorly indurated clays, based on the current state of knowledge. It will describe the reference design and present the arguments to sustain the safety and feasibility of construction and operation of the GDF design in poorly indurated clays.

This self-supporting report will be supported by a set of underlying reports containing more scientific and technical detail. The target audiences for the underlying reports are experts requiring detailed information on the safety arguments and their substantiation and, more widely, experts requiring detailed information on a specific
methodological, scientific or technical area referred to in the SFC-1. The report will allow to intensify a comprehensive dialogue with the safety authority.

The preliminary structure of the SFC-1 report is illustrated in Figure 2 and comprises the following:

- The Assessment Context which is composed of two chapters: the introduction describing a.o. the boundary conditions of the SFC, the organisation of the safety case and the safety strategy.
- The Assessment Basis containing the basic information on which the safety assessments can be performed. The assessment basis is in turn further divided into two parts covering the scientific basis and the technical basis:
  - The scientific basis is subdivided into four disciplines: the Waste Characteristics, the Engineered Materials (cementitious material and metal components), the Natural Components (poorly indurated clays and surrounding geological layers), and the Migration (transportation of solutes) in poorly indurated clays.
  - The technical basis is subdivided into the design development of the Monolith B, the design development of the Supercontainer, the Design and Construction of the GDF, and the Operation and Closure of the GDF
- The System Evolution describing the expected effect of internal and external drivers.
- The Safety Assessments including aspects of radiation protection, operational safety and long-term safety.
- A conclusion which provides a synthesis of the arguments supporting the claim that disposal of category B and C waste in poorly indurated clays is safe and feasible. Recommendations and a planned way forward will be given to tackle the remaining open questions or knowledge gaps related to safety and feasibility. This synthesis will provide the elements paving the way to site selection and site-specific SFCs.

The safety and feasibility statements are a central methodological tool in SFC-1. These statements consist of claims regarding how the disposal system is expected to perform, and its properties relevant to operational and long-term safety and to feasibility. These statements are organised in a structured and hierarchical form, with lower-level claims underpinning higher-level claims. The establishment of safety and feasibility statements provides several functions:

- The statements cover all aspects of the SFC, and are used to structure the safety case reports.
- By providing a synoptic view, the safety and feasibility statements provide a tool to steer the RD&D. All open issues are related to a safety and feasibility statement, allowing their prioritisation in the RD&D programme.
- The structure of the statements will be used in the uncertainty analysis to evaluate the impact of perturbing processes, events and associated uncertainties on the safety statements underpinning the safety functions of the disposal system.

As part of the methodological tools, a robust verification process of SFC-1 will be conducted (e.g. internal and external peer reviews of the detailed supporting studies and methodologies, organisation of a reading committee, use of verification templates).

**Figure 2: Preliminary structure of the SFC-1 report**
The optimeering methodology

Within the framework of SFC-1, special attention has been given to the traceability of the design option decisions. Indeed, for several GDF design items, various design options exist. For major GDF design items which have high impact on the safety and/or cost, the selection of a specific design option (decision making) is required to be fully justified. To do this, ONDRAF/NIRAS has developed an optimeering methodology. This methodology is a robust, transparent, systematic and traceable design options assessment process that enables identification and assessment of alternative systems and designs and identification of a preferred option among alternative designs. The optimeering takes into consideration various criteria which reflect the four main dimensions of ONDRAF/NIRAS, i.e. environment and safety, ethics and society, science and technology, and economy and finance.

Two types of options assessment are considered in the optimeering methodology:

- Strategic options assessment, which is mostly concerned with assessing what to do (e.g. what is the best layout of galleries and shafts in a GDF?)
- Specific design or technology (to demonstrate Best Available Techniques (BAT)) option assessment, which is normally concerned with how to implement the GDF (e.g. how should the galleries be designed and dimensioned?).

The design options assessment process (i.e. optimeering) is divided into five stages so that it can be applied logically, and the results from each stage can be checked for adequacy, before moving on to subsequent stages:

- Stage A: Define the objectives and scope of the design study.
- Stage B: Identify possible alternatives and credible options.
• Stage C: Assess the relative strengths and weaknesses of each credible option using relevant attributes.

• Stage D: Review the outcome of the options assessment (identify uncertainties and assess the sensitivity).

• Stage E: Report the results and identify any further work required.

A key objective of this staged process is to demonstrate a thorough consideration of available options. Once all reasonable options have been identified, a high-level screening is applied to identify any obviously non-viable options and, thus, by elimination, identify a short-list of options that can credibly satisfy the design study objective. The short-listed options are then assessed against a series of attributes concerned with safety, environmental protection, technical viability, regulatory and stakeholder issues, and cost.

The preferred option is the one that meets all statutory requirements and provides a reasonable balance of performance across all important attributes.

The main benefit of the optioneering is to provide transparency to the decision making process and lead to options being considered in greater detail.

Optioneering has been applied in earlier research work by ONDRAF/NIRAS, such as the selection of the supercontainer concept and the optimisation of the GDF layout, and is currently being applied to further optimise the reference design (e.g. optimisation of the length of the disposal galleries).

The safety assessment methodology

Safety assessments are carried out in two main phases: a preparatory phase and a formal phase. The aim of preparatory safety assessments is to identify potentially safety-relevant uncertainties and to provide quantitative assessments of their impact on system performance and safety. This phase is characterised by intense interactions between the three main groups of expertise - safety, phenomenology and technology - and leads to the development and refinement of the assessment basis, based on the safety concept and in agreement with the objectives and the subsequent requirements set for the current programme stage. Formal safety assessments aim to show in a quantitative manner, why the disposal system under consideration can be judged to be safe, satisfying all relevant regulatory and stakeholder requirements relating to the current programme stage.

Due to the generic aspect of this SFC, the safety assessment exercise is broader than the safety assessment of a specific RD&D site. Specific objectives of the assessment are to:

• Identify the key features of the disposal system that provide long-term safety. How do these safety-relevant features behave at generic sites?

• Identify the performance targets of the safety functions. A performance target is defined here as the minimal performance that the system should have with respect to a safety function to be considered effective. The performance targets are estimated on the basis of the required safety target(s) that the disposal system as a whole must achieve. The performance target is a tool to evaluate safety assessment needs and RD&D prioritisation

• Investigate the limits of the analysis of a generic site: What is the impact of the spatial variability of the region investigated on long-term safety, or, more generally, what is the impact of site-specific elements (e.g. hydraulic gradient)?

These tasks are performed, among others, by inverse modelling and sensitivity analysis during the preparatory phase. They guide identification of the requirements and
prioritisation of the RD&D. Scenarios will also be identified within SFC-1. A reference case will be derived for each of the generic sites defined for SFC-1, based on a conservative hypothesis, to address knowledge uncertainties and known spatial variabilities. The derivation of other scenarios and cases will be performed by analysing the impact of the uncertainties and spatial variabilities on the safety statements related to the long-term safety functions.

Also in line with the generic approach for the sites investigated, the surface and any confined aquifers, as well as the biosphere, are modelled in a stylised way. The most influential parameters in the model conceptualisation are retained in this stylisation.

**Conclusion**

In absence of political decision and legal framework, a GDF in poorly indurated clays is the current reference option considered for the ONDRAF/NIRAS RD&D programme. In line with international practice, ONDRAF/NIRAS intends to produce a series of SFCs. SFC-1 will be a methodological SFC aiming to test the methodological tools developed by ONDRAF/NIRAS, and illustrate the safety and feasibility of a GDF in poorly indurated clays (generic geological sites will be analysed). This approach is preferred to an in-depth study of specific RD&D sites. These generic cases (representative geological environments) are considered sufficient at this stage of the category B and C programme to guide RD&D and to test the methodological tools of the SFC (e.g. safety and feasibility statements, optioneering). This generic methodology also allows the minimum requirements for the safe and feasible disposal in poorly indurated clays to be identified (as well as the interdependences between them). SFC-1 will deliver the methodological elements required for future site-specific SFCs.

**References**


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