The safety case in support of the license application of the surface repository of low-level waste in Dessel, Belgium

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Executive summary

The modern concept of the safety case, developed by the OECD/NEA for geological repositories of high- and medium-level waste has been successfully applied by ONDRAF/NIRAS for a surface repository for Category A waste (i.e. low-level waste) in Belgium in the current project phase 2006-2012. This resulted in the submission on 31 January 2013 by ONDRAF/NIRAS of an application for a "construction and operation license" to the safety authorities. The benefits of using the notion of the safety case have been that: *i)* safety has been incorporated in an integrated manner within all assessment basis, design and safety assessment activities; *ii)* the process of development of the license application has gained in clarity and traceability; *iii)* the documentation of the license application contains multiple lines of argumentation for safety rather than argumentation based only on quantitative radiological impact calculations. To offer a comprehensive view on the safety argumentation and its development, it has been found useful to develop the argumentation not only along a safety statements structure but also along the safety report structure.

Introduction

ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials, is responsible for the management of all radioactive waste on Belgian territory. In doing so, ONDRAF/NIRAS is aiming at developing and applying sustainable solutions, which can guarantee the protection of humans and the environment, now and in the future. ONDRAF/NIRAS activities integrate four aspects: science and technique, ecology and safety, economy and finance, and ethics and society.

The development of a concept and a design for a repository and its safety assessment is an iterative process, punctuated by the submission to the government and/or regulatory authorities of safety cases supporting the decision to proceed to the next programme stage. A safety case consists of a set of key documents containing the safety arguments and the key elements of the substantiation of these safety arguments and supporting documents.

A safety case (Safety and Feasibility Case 1) (Capouet, 2014) is currently being prepared by ONDRAF/NIRAS for Category B and C wastes [corresponding to intermediate- and high-level wastes according the classification in the IAEA General Safety Guide GSG-1 (2009)].

The modern concept of the safety case, developed by the OECD/NEA (2004) for geological repositories of high- and medium-level waste, has been successfully applied for a surface repository for Category A waste [low-level waste (IAEA, 2009)] in Belgium in the current project phase 2006-2012. This resulted in the submission on 31 January 2013 by ONDRAF/NIRAS of an application for a "construction and operation license" to the safety authority, the Federal Agency for Nuclear Control (FANC) (ONDRAF/NIRAS, 2013).

Such widening in application of the safety case notion towards facilities other than geological repositories is an example of practical application of an emerging international consensus on a widened scope of use for safety cases reflected for example in the 2011 IAEA Specific Safety Requirements SSR-5 related to the disposal of radioactive waste in general.

This article focuses on the return of experience of the development of the safety case for Category A waste.

Structure of the safety case for Category A waste and reviews before submission of the license application

To accommodate different types of audiences, the safety case for Category A waste is composed of four levels of documents with an increasing breadth and depth of information and scientific and technical detail as the level number increases.

Level 1 is composed of a non-technical synthesis targeted at the general public (ONDRAF/NIRAS, 2013), an overview of the safety argumentation (ONDRAF/NIRAS, 2012r) and a technical summary of the Level 2 (ONDRAF/NIRAS, 2012s).

Level 2 is the safety report and is composed of 17 detailed chapters that serve as a reference for the Safety Report Level 1 (ONDRAF/NIRAS, 2012a-2012q). The safety report contains the safety arguments and the key elements of their substantiation and is written for technical experts.

Levels 3 and 4 supporting documents are the technical reports that have been worked out by and/or on behalf of ONDRAF/NIRAS and bear out the safety arguments described in the Safety Report Level 2. The Level 3 documents describe and substantiate the applied methodologies for development of the scientific basis, the design development and the safety assessments (ASM – assessment methodologies). The Level 4 documents are the application of the methodologies. They describe the scientific and technical basis, the development of the design and its implementation and the development of the safety assessments.

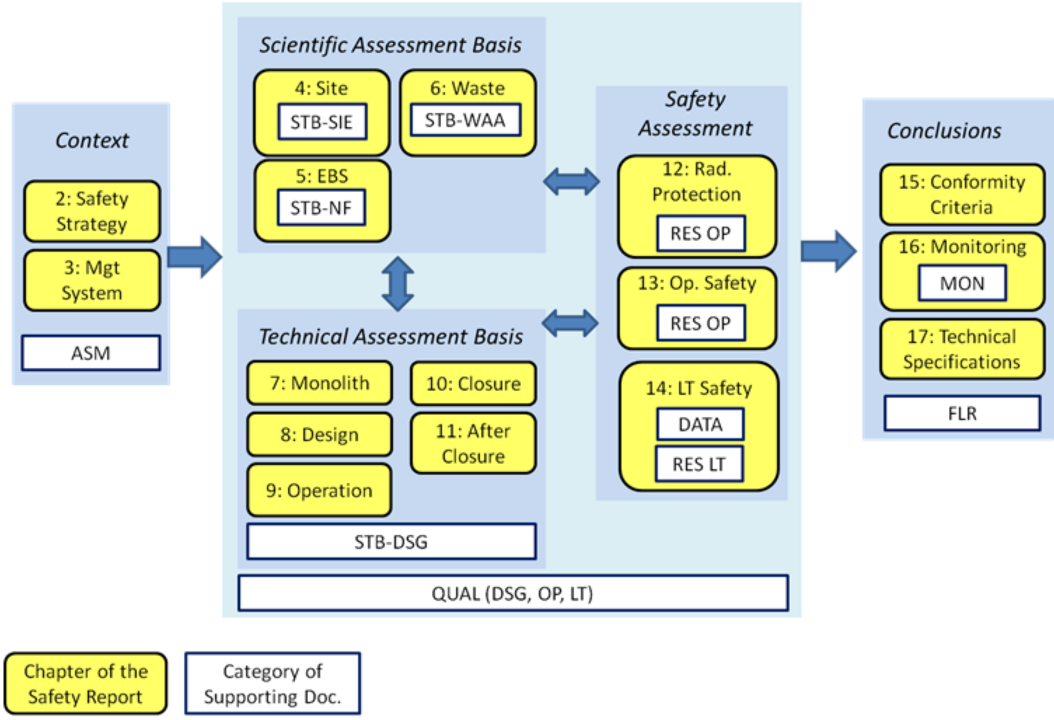
So as to provide traceability of Level 4 documents towards Levels 3, 2 and 1 and towards the safety arguments, a further classification of Level 4 is made into different areas of safety arguments and their substantiation:

- STB: The scientific and technical bases related to: *i)* the site and the environment (STB-SIE); *ii)* the near field, i.e. the multi-layer cover and the cementitious barriers (STB-NF); *iii)* the waste acceptance of category A waste (STB-WAA); *iv)* the design development and description of the components (STB-DSG).
- DATA: The data used for selecting parameter values in the calculations.
- QUAL: The qualification, verification and validation files of models and codes for design development (QUAL-DSG), operational safety assessment (QUAL-OP) and long-term safety assessment (QUAL-LT).
- RES: The results of: *i)* operational safety assessment (RES-OP); *ii)* long-term safety assessment (RES-LT).
- MON: The monitoring programme.
- FLR: The further lines of reasoning including FEP management and uncertainty management.

The target audiences of the Level 3 and Level 4 reports are experts requiring detailed information on the safety arguments and their substantiation and, more generally speaking, experts requiring detailed information on a specific methodological, scientific and technical area referred to in the safety arguments.

Figure 1 illustrates how the organisation of the Level 3 and 4 supporting documents fits within the structure of the safety report.

Figure 1: Organisation of the Level 3 and 4 supporting documents



The safety case has undergone extensive internal and external peer reviews at various levels before its finalisation for the current license application. The various internal and external reviews of the detailed supporting studies and methodologies have been done by a broad involvement of national and international expertise. At a high level, key aspects of the ONDRAF/NIRAS preliminary safety case (version November 2011), have undergone an international peer review organised by the NEA (OECD/NEA, 2012). As a result of discussions during this peer review and as a result of the findings of the peer review, the safety case has been further improved before it was submitted as part of the license application on 31 January 2013. This international peer review has proved to be a fruitful exercise for improvement and clarification of the safety case before it was submitted to regulatory scrutiny by the Belgian nuclear regulator FANC.

Safety strategy

An important preparatory step in the development of a safety case is the establishment of a *safety strategy*, i.e. a high-level integrated approach adopted for achieving safe disposal.

The safety strategy is framed inside an overall iterative management process firmly focused on safety, i.e. the *overall safety approach*. In the overall safety approach, the scientific assessment basis, the design and the safety assessments are all three based upon the safety strategy. This ensures that the developed design and disposal system already take into account all fundamental requirements to ensure safety. With the safety assessments for the developed disposal system, it is checked and confirmed that safety is ensured and the effect of various types of residual uncertainties are estimated as an input for prioritisation and decisions for the next iteration of the disposal programme.

Throughout the development and implementation of the repository, various iterations are performed, ultimately leading to a fully constructed, filled and closed i.e. fully implemented, disposal facility for which there is reasonable assurance of long-term safety. This iterative development and implementation is not only applicable before initial construction, but remains applicable such that before key decisions, e.g. the start of waste emplacement in the repository, the safety case and safety assessments are updated accordingly. Furthermore, a regulatory system of periodical safety revisions is also applied, leading to periodical updates of the safety case.

Through disposal of radioactive waste on the surface, the waste is emplaced in facilities that are directly placed in the biosphere. This implies that the long-term safety after closure of the facility resides on four essential pillars:

1) the properties of the different components of the facility to passively contain and isolate the radioactive waste from humans and the environment;
2) the properties of the disposal site that contribute to this passive containment and isolation (e.g. non aggressive environment);
3) the measures taken to limit the long-lived activity in the waste that can be disposed of, taking into account the containment and isolation performance of the facility;
4) the control and surveillance measures in the repository and its direct surroundings in order to prevent human activities that could perturb the passive containment and isolation provided by the disposal facility.

These pillars rely on the notions of containment and isolation provided by the disposal facility and its constituting systems, structures and components (SSC). The containment and isolation functionalities have been further detailed into *safety functions* that the system of SSC have to fulfil in order to protect humans and the environment, now and in the future.

The safety functions, SSC and different time frames are grouped into the "safety concept" which constitutes a key input towards both design development (establishment of design requirements and conformity criteria) and safety assessment (establishment of scenarios and models based upon the key SSC and safety functions). The safety concept is illustrated in Figure 2.

It is assumed that inadvertent human intrusion by control and surveillance as long as nuclear regulatory control and associated access controls are operational during Phase III (Figure 2). After Phase III, the physical barriers formed by the different components of the facility still provide some means for reducing the likelihood and possible radiological consequences of inadvertent human intrusion.

The safety concept was further detailed in a table describing which systems, structures and components (SSC) have to fulfil which major safety functions during which time frames (see Figure 3). The roles of the various SSC are then categorised to indicate the relative importance of the safety functions that a given SSC fulfils. The categories are "main" (i.e. it must be demonstrated and verified that the SSC, under normal conditions, will fulfil the required long-term safety function) or "contribute" to the fulfilment of a certain long-term safety function. The safety concept is thus constituted of the SSC and safety functions with "M" roles.

The safety concept further constitutes a framework for documenting the various safety arguments developed during establishment of the scientific assessment basis, the development of the design and the safety assessments. With this tool it is also possible to structure the remaining key uncertainties, which can e.g. be reduced by further research, development and demonstration (RDD).

Figure 2: Safety concept

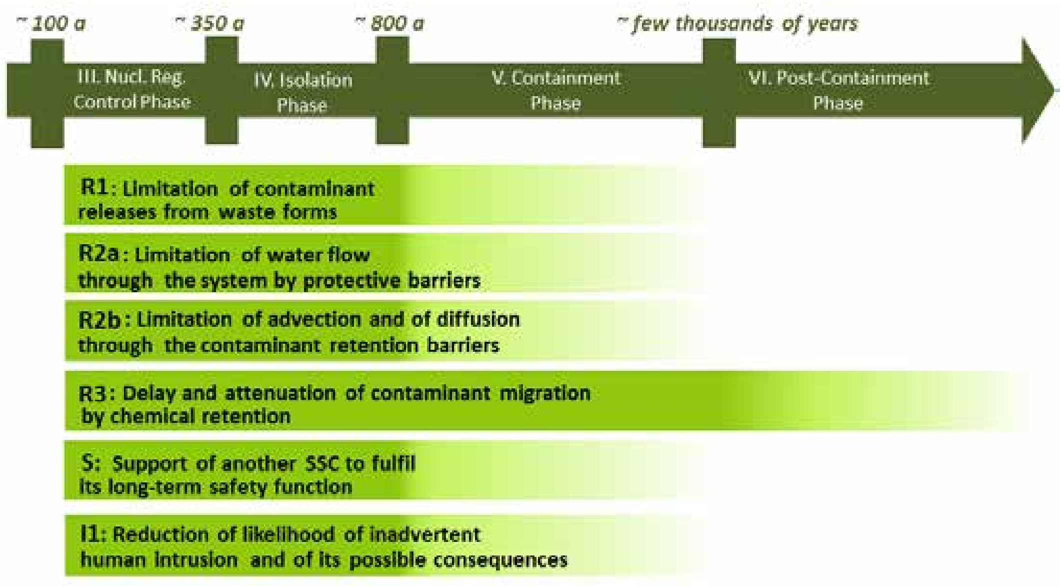


Figure 3: Principle for the development of the safety concept

	Long-Term Safety Function 1			Long-Term Safety Function 2			...
	Phase III	Phase IV	Phase V	Phase III	Phase IV	Phase V	
SSC 1	M	M	C	M	M	C	
SSC 2	M			M			
...							

Structuring the safety arguments around a central assertion

The safety arguments structured around the safety concept are part of a broader set of safety arguments (ONDRAF/NIRAS, 2012r). The safety arguments have been structured around the following central assertion:

In the current programme step of the disposal programme of Category A waste, ONDRAF/NIRAS has developed within its integrated project and its safety approach, a safety strategy and a safety concept. This strategy and concept have resulted in a design of a surface disposal facility for Category A waste at Dessel, that is optimised, of which the construction and operation are feasible and that is robust and safe. The disposal programme is ready for the next programme steps.

This assertion is supported by seven primary safety statements:

1) The current programme step of the ONDRAF/NIRAS disposal programme for Category A waste is framed in a clear decision context that successfully integrates technical and societal aspects.

2) With the integrated project and the safety approach, ONDRAF/NIRAS has developed and applied a suitable management system for the development of the safety case.

3) The safety strategy and safety concept are means to ensure a structured, clear and traceable development and documentation of the disposal and its safety argumentation.

4) The necessary knowledge base supports the assessment of facility feasibility, robustness and safety.

5) ONDRAF/NIRAS has shown that the design, construction, operation and closure of the disposal facility are radiologically optimised and feasible to implement.

6) ONDRAF/NIRAS has shown that the proposed repository is safe and robust. The assessed radiological impacts respect all safety criteria.

7) ONDRAF/NIRAS has prepared the next programme steps and has proactively started RD&D activities in order to increase the understanding of the performance of the disposal system, reduction of uncertainties, increasing confidence in the safety margins and further optimisation of the facility and its radiological contents with regard to (long-term) radiation protection and to flexibility of construction and of operation.

Each primary safety statement is supported by several secondary safety statements which are then argued with the various elements available throughout the safety case. For example:

- An important element contributing towards the integration of scientific and social aspects are the partnerships STORA and MONA that ONDRAF/NIRAS has established with the local municipalities of Dessel and Mol.

- Feasibility of construction and operation rests importantly on QA/QC programmes, a graded approach for approval from the operator and regulator for accepting waste in the repository and on the integrated management system (IMS) of ONDRAF/NIRAS (2012c). Other elements contributing to this are on-site tests such as the settlement test to verify feasibility, the construction of prototype monoliths and the demonstration test to test the constructability of modules (see Figure 5).

Figure 5: Tests to demonstrate feasibility of construction

The presentation of the safety arguments is done in parallel to a synthesis along the structure of a “safety report” (ONDRAF/NIRAS, 2012a-2012q, 2012s) that stresses more the process by which the safety case has been developed (see Figure 1):

1) establishment of context and safety strategy;
2) establishment of scientific assessment basis and freezing of data;
3) based on previous steps, establishment of the design of the disposal facility and of its implementation, i.e. construction, operation, closure, oversight (technical assessment basis) and freezing of data;
4) based on previous steps, establishment of safety assessments;
5) based on previous steps, establishment of operational conditions, i.e. waste conformity criteria, monitoring programme and technical specifications of the repository.

The combination of both types of reporting conveys a comprehensive view on the safety argumentation and its development, rather than one of the two reports taken separately.

Lessons learnt

Important challenges for surface disposal included:

1) The predominant role of engineered barriers leading to special attention towards their construction and verification.
2) The dominant role of the waste source term, leading to special attention towards the derivation of waste conformity criteria such as maximum allowable activity concentrations in the waste and maximum allowable activity in the repository as a whole.
3) The treatment in safety assessments of the evolution and related uncertainties in physical and chemical containment properties of cement-based materials (which are the predominant long-term safety barriers for surface disposal). This challenge has been tackled by a combination of conservative bounding analysis for derivation of waste conformity criteria and a set of different scenarios and assessment cases to explore uncertainties and the safety margins of the bounding analysis.

Conclusions

The license application documentation for the surface repository of Category A waste at Dessel has been established successfully along the lines of the safety case notion, initially conceived for programmes of geological disposal for medium- and high-level waste. The benefits of this have been that:

1) Safety has been incorporated in an integrated manner within all assessment basis, design and safety assessment activities.
2) The process of development of the license application has gained in clarity and traceability.
3) The license application documentation contains multiple lines of argumentation of the safety rather than argumentation based on quantitative radiological impact calculations only. To offer a comprehensive view of the safety argumentation and its development, it has been found useful to develop the safety argumentation both along a safety statements structure and along a safety report structure.

The safety case constitutes a key element of documentation supporting the license application towards a “construction and operation” license for the surface repository at Dessel. With the licensing process being started, ONDRAF/NIRAS is preparing the next programme steps of construction and operation. ONDRAF/NIRAS is currently addressing amongst other things the establishment of the QA/QC programme of cement-based materials (which are the predominant long-term safety barriers for surface disposal) and refinements related to the hydraulic conductivity of concrete, which were important topics for further work as identified by the NEA peer review (OECD/NEA, 2012).

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