Report on the safety assessment methodology

OPERA-PU-NRG2121

Radioactive substances and ionizing radiation are used in medicine, industry, agriculture, research, education and electricity production. This generates radioactive waste. In the Netherlands, this waste is collected, treated and stored by COVRA (Centrale Organisatie Voor Radioactief Afval). After interim storage for a period of at least 100 years radioactive waste is intended for disposal. There is a world-wide scientific and technical consensus that geological disposal represents the safest long-term option for radioactive waste.
Geological disposal is emplacement of radioactive waste in deep underground formations. The goal of geological disposal is long-term isolation of radioactive waste from our living environment in order to avoid exposure of future generations to ionising radiation from the waste. OPERA (OnderzoeksProgramma Eindberging Radioactief Afval) is the Dutch research programme on geological disposal of radioactive waste.
Within OPERA, researchers of different organisations in different areas of expertise will cooperate on the initial, conditional Safety Cases for the host rocks Boom Clay and Zechstein rock salt. As the radioactive waste disposal process in the Netherlands is at an early, conceptual phase and the previous research programme has ended more than a decade ago, in OPERA a first preliminary or initial safety case will be developed to structure the research necessary for the eventual development of a repository in the Netherlands. The safety case is conditional since only the long-term safety of a generic repository will be assessed. OPERA is financed by the Dutch Ministry of Economic Affairs, Agriculture and Innovation and the public limited liability company Electriciteits-Produktiemaatschappij Zuid-Nederland (EPZ) and coordinated by COVRA. Further details on OPERA and its outcomes can be accessed at www.covra.nl.

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Contents

Summary

The Safety Assessment Methodology, as described in the OPERA research plan and as implemented in the OPERA research projects, has been evaluated against the Safety Assessment Methodologies provided in IAEA SSG-23 (IAEA, 2012) and NEA reports 3679 (NEA, 2004) and 78121 (NEA 2013). The OPERA safety assessment methodology was found to be fully consistent with IAEA SSG-23. NEA 3679 and 78121 were of value in providing a list of criteria for guiding and evaluating the safety assessment to improve the quality of the safety case.

Samenvatting

De methodiek voor veiligheidsbeoordeling zoals beschreven in het OPERA onderzoeksplan en in de OPERA onderzoeksprojecten is geïmplementeerd is vergeleken met de methodes zoals beschreven in IAEA SSG-23 (IAEA, 2012) en NEA rapporten 3679 (NEA, 2004) en 78121 (NEA 2013). De OPERA methodiek bleek volledig consistent met IAEA SSG-23. De NEA rapporten 3679 en 78121 voorzien in een lijst richtlijnen en evaluatiecriteria voor de veiligheidsbeoordeling ten behoeve van de Safety Case.

1. Introduction

1.1. Background

The five-year research programme for the geological disposal of radioactive waste – OPERA- started on 7 July 2011 with an open invitation for research proposals to be based on the OPERA Research Plan (Verhoef, 2011; Section I, p.20,21). The work on Task 2.1 *Definition of the Safety Case started in June 2012.*

1.2. Objectives

The objective of this task, OPERA Task 2.1.2 “Safety Assessment Methodology, was to define the overall methodology and strategic framework for the safety assessments that will be performed within OPERA WP7 (Scenario Development and Performance Assessment) should be defined.This was achieved by evaluating the Safety Assessment Methodology that is described in the OPERA research plan and is implemented in the OPERA research projects against the guidelines for safety assessment provided in IAEA SSG-23 (IAEA, 2012) and NEA 3679 (NEA, 2004) and 78121 (NEA 2013).

1.3. Realization

This report was prepared by the OSCAR consortium, comprising of NRG, TNO, GRS and EnviroLogic.

1.4. Contents of this Report

Chapter 1 has presented the project background and purpose of the OPERA Safety Assessment Task 2.1.2.

Chapter 2 presents two Safety Assessment Methodologies, one described in IAEA SSG-23 (IAEA, 2012), the other reported in NEA 3679 (NEA, 2004).

Chapter 3 reflects on the methodological framework described in the OPERA Research Plan and specific on-going OPERA projects in the light of the safety assessment methodologies provided by IAEA and NEA.

Chapter 4 concludes with: a) a high level description of safety assessment methodologies, b) approaches for quantifying the behaviour of a repository, including the treatment of uncertainty, c) an approach to the assessment of possible future states of the repository (i.e., scenarios through the use of FEPs) and d) the ability of the safety assessment methodology to be incorporated into the OSC.

2. Safety Assessment Methodologies

The Safety Assessment Methodology that will be used in the OPERA projects is broadly defined in the OPERA research plan and subsequent contracts with the research organizations. The aim of this report is to provide a framework for the assessment methodology that fits in the OPERA Safety Case, rather than to describe the assessment methodology itself.

The OPERA Research Plan is based primarily on the NEA report: *Post-closure Safety Case for Geological Repositories: Nature and Purpose* (NEA, 2004). The NEA logic for the safety case is defined as: *assessment basis* + *analyses* => *evidence*. Inherent in this logic is the safety assessment, which is split into three parts: assessment basis (data, models), analyses (calculations), and results (compliance with dose and risk criteria).

For the OPERA Safety Case structure, the OSCAR project proposed using the IAEA Specific Safety Guide SSG-23, *The Safety Case and Safety Assessment for the Disposal of Radioactive Waste* (IAEA, 2012).

SSG-23 separates the Safety Case into the eight components shown below.

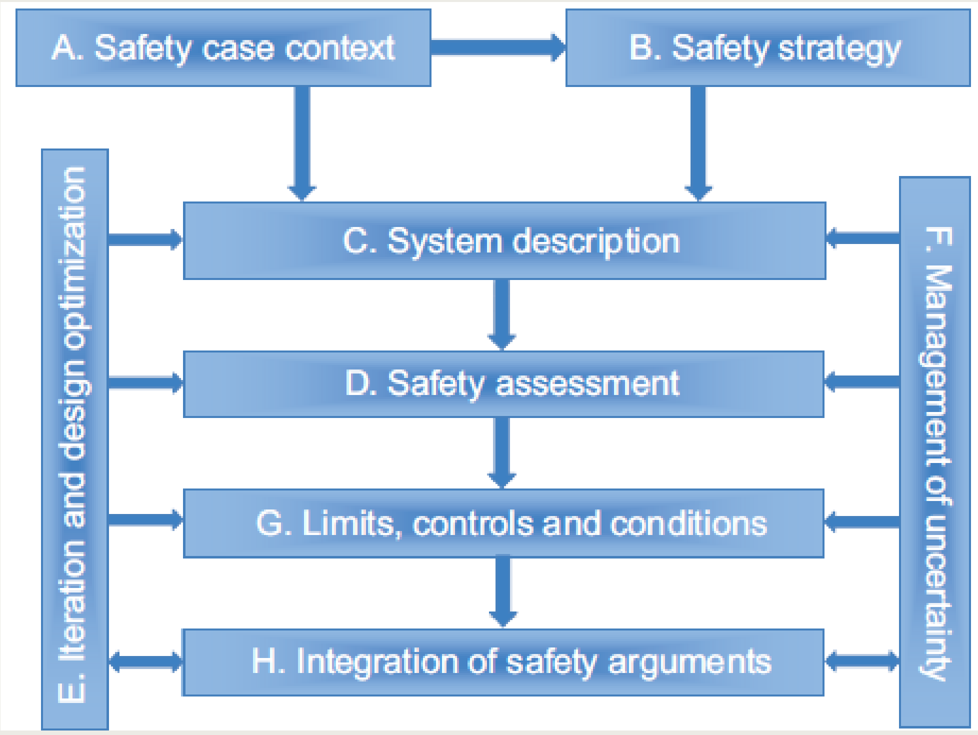

Figure 2-1 Components of the Safety Case (IAEA 2012; p.16)

Safety Assessment (D) is the key component of the IAEA SSG-23 safety case structure. SSG-23 also provides guidance on the sequence of steps inside the safety assessment.

This OPERA report relates the safety assessment methodology found in the OPERA research plan to the Safety Assessment found in the safety case. In addition, the NEA's list of criteria for guiding and evaluating the safety assessment (NEA, 2004; NEA 2013) is recommended for establishing a more defensible safety assessment.

2.1. IAEA SSG 23: The Safety Case and Safety Assessment for the Disposal of Radioactive Waste

IAEA uses the term 'safety assessment' in the Specific Safety Guide (SSG-23) to refer to all quantitative, safety-relevant assessments of the safety case for the development, operation, and closure of the disposal facility. The safety assessment, as defined by the IAEA, also addresses non-radiological issues and organizational and managerial requirements for quantifying safety. A graphical presentation of this is given below.

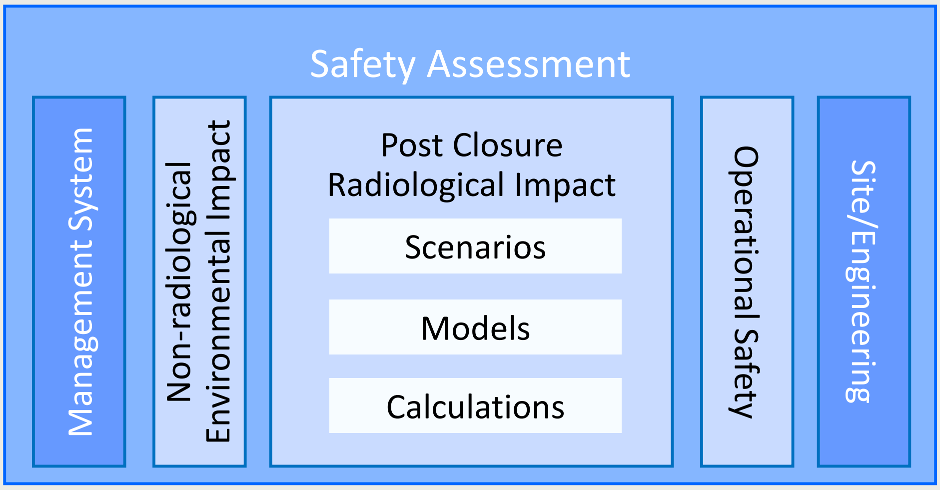

Figure 2-2 Aspects included in safety assessment (IAEA 2012; p. 17)

Geologic disposal is fundamentally different from other radioactive waste management activities in the need to assure long-term, post-closure safety. Therefore, assessing post-closure radiologic impacts is key to the entire development of a Safety Case, from pre-site selection to final closure. IAEA (IAEA 2012, p. 45) defines the following seven key components in their post-closure safety assessment methodology:

1. Specification of the context for the assessment;
2. Description of the waste disposal system;
3. Development and justification of scenarios;
4. Formulation and implementation of models;
5. Performance of simulations and analysis of results, including sensitivity and uncertainty analyses;
6. Comparison with safety criteria;
7. Review and modification of the assessment, if necessary (i.e. iteration).

Some of these key components (context for the assessment, description of the waste disposal system, evaluation of results) overlap with the respective components of the Safety Case. This is a natural consequence of post-closure radiological impact assessment being one element of the broader safety case (IAEA 2012, p. 45).

Chapter 5 of SSG-23 provides additional details for each of the seven key components, as shown in the table below. Text included in Chapter 5 also provides for internal iteration or refinement of the safety assessment model. This iteration could be considered another step in the safety assessment process.

Table 2-1 Overview of items discussed in the seven key components of the Safety Assessment

1. CONTEXT FOR THE ASSESSMENT
Purpose of the assessment Philosophy underlying the assessment Use of different approaches to assessment Probabilistic and deterministic approaches Conservative assessments and realistic assessments Regulatory framework End points for the assessment Receptors Time frame for the assessment
2. DESCRIPTION OF THE DISPOSAL SYSTEM
The collection of the data needed for the quantitative assessment
3. DEVELOPMENT AND JUSTIFICATION OF SCENARIOS
Consider the performance of the disposal system under both present and future conditions
4. FORMULATION AND IMPLEMENTATION OF ASSESSMENT MODELS*
Development of Conceptual and Mathematical Models Identification and Selection of Parameters and their Values
5. PERFORMANCE OF CALCULATIONS AND ANALYSIS OF RESULTS
Management of uncertainties Sources of uncertainty Uncertainty and sensitivity analyses Treatment of scenario uncertainties
6. COMPARISON WITH ASSESSMENT CRITERIA
Estimates of doses and risks compared with appropriate criteria
7. REVIEW AND MODIFICATION OF THE ASSESSMENT
This key component allows iterations in the safety assessment. Moreover, a safety case should also address follow up programs and actions.

*The IAEA SSG23 (IAEA 2012; p. 16) also allows for a key component "Refinement of the assessment models" with each step in the disposal process.

Experts from the authorities, supported by consultants and IAEA staff wrote SSG-23. The IAEA Specific Safety Guides are consistent with the IAEA overarching safety fundamentals published in the GSR series (General Safety Requirements) and the SSR-series (Specific Safety requirements). Appendix 1 gives a short overview of two IAEA documents: GSR Part 4-*Safety Assessment for Facilities and Activities* and SSR-5 *Disposal of Radioactive Waste*.

2.2. NEA report 3679: Post-closure Safety Case for Geological Repositories

The NEA (NEA, 2004) does not clearly separate and identify all of the components of a safety assessment in their Safety Case concept. Instead a few major aspect of the safety assessment reside in separate NEA components of the safety case including the 'assessment basis' and 'evidence, analyses and arguments’ (see the following table).

Table 2-2 Safety Assessment Components of the Safety Case in NEA 3679

Safety case elements (NEA 3679)	
Assessment Basis	
Scientific and technical information and understanding	
System Concept	
Methods, models, computer codes and databases	Core ingredients of the Safety Assessment
Evidence, analyses and arguments	Core ingredients of the Safety Assessment
Compliance with dose and risk criteria	Core ingredients of the Safety Assessment
Safety indicators	Core ingredients of the Safety Assessment
Adequacy of the strategy to manage uncertainties and open questions	
Strength of geological disposal as a waste management option	

In addition to the core components, NEA defines a safety assessment to include a presentation of the system concept and the scientific understanding underpinning the assessment models, data, parameters, and overall understanding of the repository system. The NEA also calls for an evaluation of the strategy of managing uncertainties and arguments for the strength of the concept.

The benefit of the NEA's approach to safety assessment (NEA, 2004; p.39-40) is their stipulation of a list of criteria that should be addressed by the safety assessment and related to the R&D program:

- the approach is logical, clear and systematic;
- the assessment is conducted within an auditable framework;
- the approach has been continually improved through an iterative process;
- the approach has been subject to peer review;
- effective communication has taken place between those engaged in research and site investigation programs and safety assessors to ensure that safety assessors are informed of all relevant information as it is acquired;
- sensitivity analyses have been carried out to ensure that scenarios and calculation cases address key uncertainties affecting the performance of the disposal system;
- suitable criteria have been developed for the exclusion or inclusion of features, events and processes (FEPs) from scenarios for evaluation;
- features, events and processes (FEPs) to be included in the assessment are audited against international FEP lists;
- evidence supporting the choice of scenarios, models and data comes from a wide range of sources, including field, laboratory and theoretical studies, and multiple lines of argument are, where possible, made to support the choice of particular scenarios, model assumptions and parameter values;
- mathematical models are based on well-established physical and chemical principles, or on empirical relationships with an experimental basis that supports their applicability in conditions (e.g. scales of space and time) relevant to the assessment;
- computer codes are developed in the framework of a QA procedure, and verified, for example by comparison with analytical solutions and alternative codes and confidence is increased by means of the simulation of experiments and of natural settings; and
- a clear strategy and methods exist for the handling of uncertainties.

The NEA report was written by the key experts of six Waste Management Organizations (supported by NEA editors) and is based on their experience in preparing safety cases and safety assessments. NEA reports are stand-alone documents, and are not part of a series or a hierarchy of documents.

2.3. NEA Report 78121: The Nature and Purpose of the Post-closure Safety Cases for Geological Repositories

This NEA report (NEA 2013) is an update of NEA 3679, which was discussed in the previous section. This update has a more extensive treatment of safety assessment and the safety assessment has been redefined to be part of "safety assessment, evidence and arguments", which was addressed as "Evidence, analyses and arguments" in the previous NEA report. Results from the NEA MeSA project have been included in the assessment strategy flowchart (NEA 2013, p. 31).

The building blocks of the NEA safety assessment (NEA, 2013) are defined to include: *system concept description*, *scenarios in safety assessment*, *safety assessment and modelling*, *the nature of the safety assessment outcome*, and *handling of uncertainty*.

The NEA criteria for evaluating a safety assessment have been unchanged since NEA (2004).

The NEA 2013 report was written by specialists from two Waste Management Organizations, two research organizations, and two governmental departments (supported by NEA editors) and is based on their experience in preparing safety cases and safety assessments.

2.4. Discussion

IAEA SSG-23 differs from the NEA (2004 and 2012) definition and use of a safety assessment in scope and level of detail. With regard to scope, IAEA uses the term ‘safety assessment’ to refer to all assessments performed as part of the safety case. This encompasses the development, operation, and closure of the disposal facility. Note that in the current OPERA research plan - and consequently in the OPERA research program - safety assessment is limited to the long-term safety of the repository.

Next, IAEA (2012) provides more details of the safety assessment and includes the safety assessment as a unique component of the safety case.

3. The OPERA Safety Assessment Methodology

A slightly edited version of the framework provided by IAEA SSG-23 is recommended for use as the OPERA safety assessment methodology. The modification concerns only the elimination of the last step, review and modification of the assessment. Therefore the proposed safety assessment includes the following key components:

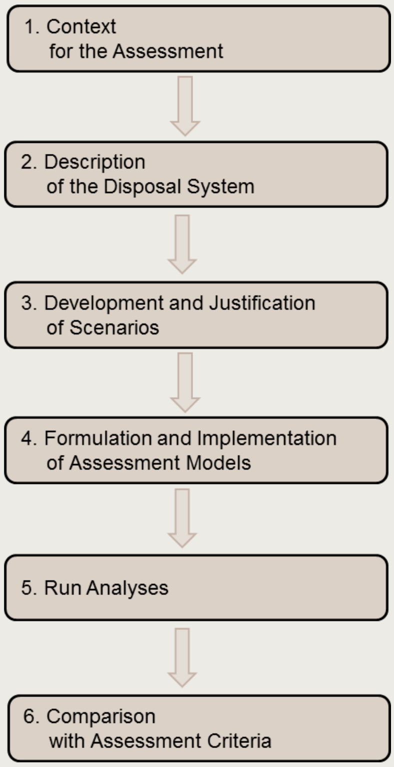

Figure 3-1 Modified IAEA SSG-23 framework the safety assessment

This proposed safety assessment methodology generally agrees with the ISAM scheme (IAEA, 2004; p.17), also presented in Figure 4 in the OPERA Research Plan (Verhoef, 2011; p.12,13)[a]. In the ISAM scheme, however, step 6 "comparison with assessment criteria", is split into "interpret results" and "compare against assessment criteria". Moreover, ISAM, developed before SSG-23 includes an iterative scheme with respect to the adequacy of the safety case. With the development of the safety case concept, that step is now part of the safety case, not of the safety assessment. Such iteration is not foreseen within the OPERA Research Plan.

The NEA (2012) criteria for evaluating a safety assessment are recommended for use with the ISAM safety assessment methodology.

In the following sections each of step of the recommended safety assessment methodology is described in more detail, including a summary of the SSG-23 description, the criteria taken from the NEA report, and the implementation in the OPERA research program.

[a] In the OPERA Research Plan, these key components are addresses as steps. Therefore in the remainder of this report 'key components' will be refered to as 'steps'.

3.1. *Context for the Assessment*

SSG-23 description
IAEA SSG-23 notes that this step (*Context For The Assessment*) in the Safety Case Component *Safety Assessment* overlaps with the Safety Case Component *Safety Case Context*. SSG-23 states that this step in the Safety Assessment relates specifically to the quantitative assessment and supplements the more general presentation in the Safety Case Component *Safety Case Context*.

Items to address in the step *Context for the Assessment* are:

- Purpose of the assessment
- Philosophy underlying the assessment
- Regulatory framework
- Endpoints for the assessment
- Time frame for the assessment

NEA criteria
The following criteria for evaluating context for the assessment are taken from the NEA 3679.

a. the approach is logical, clear and systematic;
b. the assessment is conducted within an auditable framework;
c. the approach has been continually improved through an iterative process;
d. the approach has been subject to peer review;
e. effective communication has taken place between those engaged in research and site investigation programs and safety assessors to ensure that safety assessors are informed of all relevant information as it is acquired;

OPERA Research Program
The OPERA Research Program meets these criteria as described below:

a. In the OPERA research program, the ISAM scheme is followed which is considered logical, clear and systematic. (The ISAM scheme is consistent with the SSG-23.)
b. In the OPERA Research program many milestone reports are defined in order to develop an auditable framework. All milestone reports can be made public available if necessary and/or useful.
c. In the previous Dutch research programs (OPLA and CORA) gradually evolving assessment schemes have been used. The present implementation of the scheme, based on ISAM and SSG-23, is a logical step in this sequence.
d. The OPERA safety case group reviews strategic documents, such as the safety case structure and the safety assessment methodology.
e. The OPERA research program includes expert meetings and a web portal to exchange information and to allow effective communication between the experts.

The Assessment context will be defined by the implementer (COVRA).

3.2. *Description of the Disposal System*

SSG-23 description
In IAEA SSG-23 it is noted that this step (*Description Of The Disposal System*) in the Safety Case Component *Safety Assessment* overlaps with the Safety Case Component *System Description*. SSG-23 states that this step in the Safety Assessment relates specifically to the quantitative assessment and supplements the more general presentation in the Safety Case Component *System Description*.

IAEA SSG 23 (IAEA, 2012) and NEA report 3679 (NEA, 2004) do not give specific details for this step. NEA (2013, p. 33) states that the system concept description primarily reflects:

- the identification and characterisation of the waste to be disposed of;
- the characterisation of the site;
- the characterisation of the concept, including the roles of the natural and engineered barriers and the safety functions that these are expected to provide in different time frames.

OPERA research program

For completeness of the OPERA safety assessment, the NEA (2013) description above addresses the Safety Functions of the various barriers between the disposed waste and our environment.

Knowledge database

The description of the disposal system includes the information needed for the quantitative assessment with respect to the characterisation of the waste, the site and the disposal concept.

These data will be acquired and substantiated in OPERA work packages 1, 3, 4, 5 and 6: e.g. waste characteristics (WP 1), Facility design (WP 3), EBS characterisation (WP 5.1), Near/far field characteristics (WP 5.2 and WP 4), Biosphere characteristics (WP 6).

In order to ensure that results are substantiated and information sources, underlying assumptions, choices and arguments are traceable, these will be laid down in the OPERA research reports in accordance with common principles in scientific reporting.

In order to improve traceablility and consistency, it is adviced to extend the OPERA research program by a sustainable knowledge database which will be a crucial source of information for future research and further development of the Safety Case for geological disposal in the Netherlands. A process should be developed and implemented such that all research organisations involved in OPERA will (1) contribute to this database and (2) verify that data used in their analyses are consistent with the data in the knowledge database.

The implementer (COVRA) will release the data for the safety assessment.

3.3. Development and Justification of Scenarios

SSG-23 description

Scenarios are alternative possible evolutions of the disposal system. Scenarios can be represented by structured combinations of features, events and processes (FEPs) that may affect the performance of the disposal system. IAEA SSG-23 describes two approaches for developing scenarios

1) a 'bottom-up' method and is based on developing features, events and processes by screening of international FEPs lists. Then a thorough examination of interactions between FEPs and their combination in suitable scenarios is performed.
2) a 'top-down' method for developing scenarios based on analyses of how the safety functions of the disposal system may be affected by possible features, events and processes. This step may be followed by an audit of the scenarios developed against an appropriate list of features, events and processes.

OPERA implementation

OPERA task 7.1.1 provides in a choice and the rationale for the choice of an appropriate range of scenarios. For OPERA, method 2 is used, analyses of how safety functions may be affected by FEPs, followed by a process of auditing the scenarios developed against an appropriate list of features, events and processes, including description of radiological, thermal, hydraulic, mechanical, chemical and biological processes that may affect the disposal system. Details are given in the OPERA milestone document M7111 (Grupa, 2013).

<u>NEA criteria</u>
The following criteria from the NEA 3679 aid in the evaluation of the safety assessment:

a. Are the scenarios based on a FEP catalogue
b. Suitable criteria have been developed for the exclusion or inclusion of features, events and processes (FEPs) from scenarios for evaluation;
c. Features, events and processes (FEPs) to be included in the assessment are audited against international FEP lists;
d. Evidence supporting the choice of scenarios, models and data comes from a wide range of sources, including field, laboratory and theoretical studies, and multiple lines of argument are, where possible, made to support the choice of particular scenarios, model assumptions and parameter values;

<u>OPERA research program</u>
In the OPERA research program these criteria have been met as follows:

a. An OPERA FEP catalogue has been issued (Schelland, 2013)
b. A conceptual procedure for the screening of FEPs is reported in OPAP-I working document (OPAP-I, 2012)
c. The OPERA FEP catalogue refers to the international IFEP catalogue (NEA, 2000).
d. The choice of the scenarios is also based on the experience of the project partners from the Netherlands, Belgium and Germany in their previous and on-going national programs.

3.4. Formulation and Implementation of Assessment Models

<u>SSG-23 description</u>
An assessment model will be developed consisting of the following components:

- A conceptual model. The conceptual model provides a description of the components of the system and the interactions between these components.
- A mathematical model, which is a mathematical representation of the features and processes included in the conceptual model.
- A computer code, which is a software implementation of the mathematical model that facilitates performance of the assessment calculations.

<u>OPERA implementation</u>

Conceptual model

The conceptual model applied in OPERA represents the region between the disposed waste and potential receptors (i.e. humans) in our environment. The region between the waste and the receptor is conceptually divided into compartments: the waste matrix, the engineered barriers, the clay host rock, the geosphere (including any aquifer systems) that surrounds the host rock and the biosphere. In the OPERA research program these compartments are summarized for a hypothetical repository in clay and include the waste, the engineered barrier, and clay within which the waste in placed, the geosphere including any aquifers, and biosphere (including potential receptors).

The basic premise is that the radionuclides have to move from the waste through these compartments to reach the receptors in the biosphere. The various scenarios differ in the processes that drive the radionuclide migration through each of the compartments and/or the pathways available for radionuclide transport through the compartments.

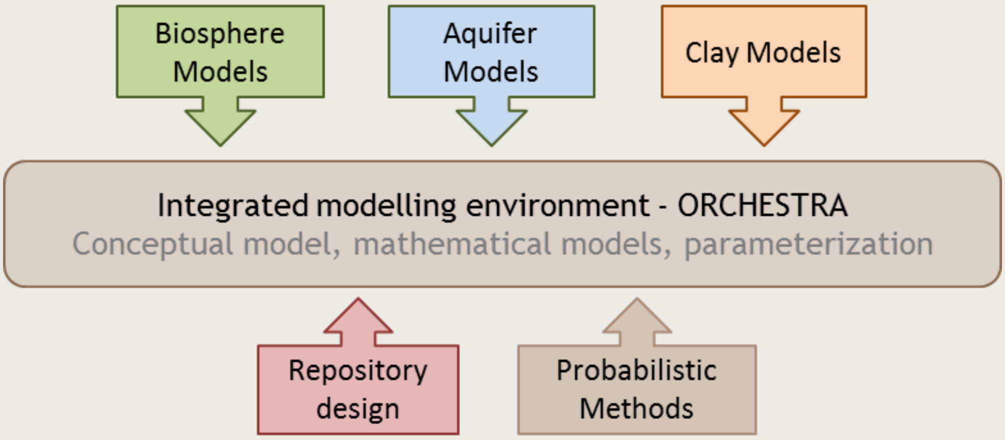

Figure 3-2 Outline of the conceptual model for formulation and Implementation of Assessment Models

Mathematical model

The scenarios will be translated into parameterized model representations of the *Clay*, *Aquifer*, and *Biosphere*, as well as into the integrated modelling environment. The integrated model will be developed in WP 7. Detailed models will be used to support parts of the integrated model. The logic is shown in the figure below.

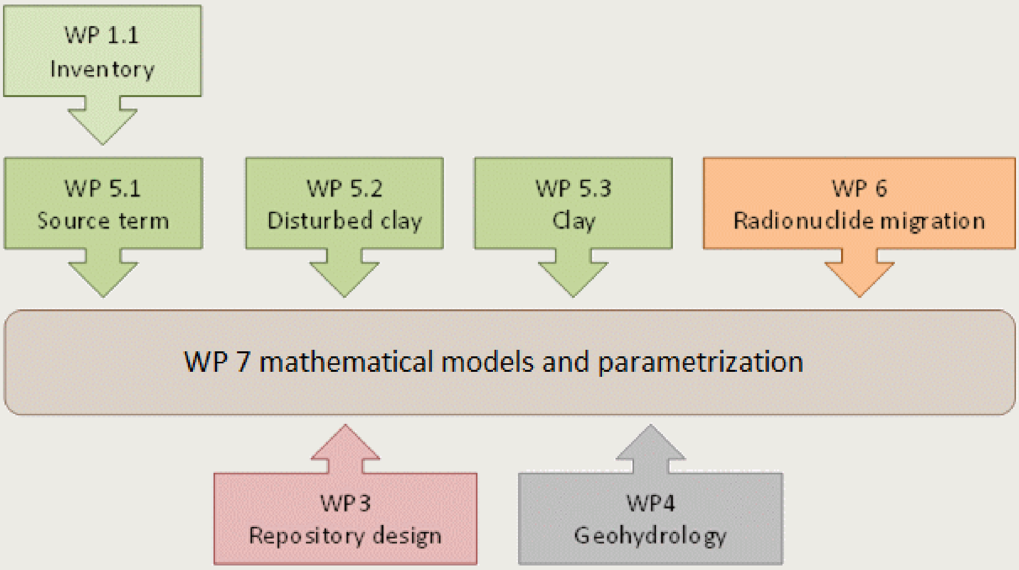

Figure 3-3 Relation between the mathematical models and the relevant OPERA Work Packages

Initial investigations have already been performed in the previous Dutch programs. Though the Dutch disposal program is in an early development stage, the OPERA research program contains already various studies to refine the knowledge about the properties of the host rock, the development of the aquifer system, and biosphere.

The integrated model of the previous Dutch research program will be used in OPERA as the initial baseline model. Refinements to the models that emerge from the OPERA research tasks will be implemented in the integrated tool. This process is shown in the figure below.

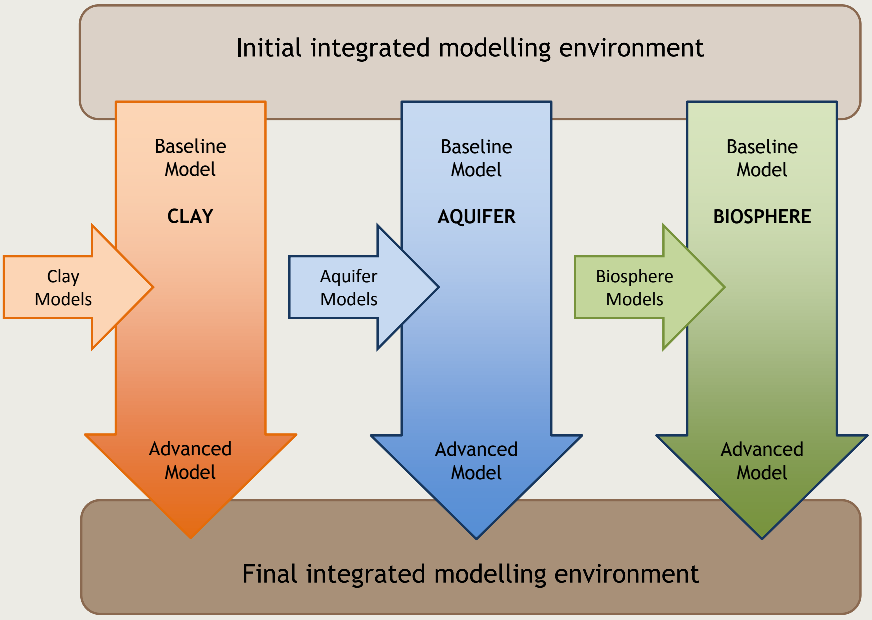

Figure 3-4 Procedure to refine the integrated safety assessment model environment

Computer code

The detailed models will be implemented in dedicated computer codes available to the experts in WP1, WP3, WP4, WP5 and WP6. The integrated model will be developed in the ORCHESTRA code and couples the three PA compartment models, viz. the Clay, Aquifer, and Biosphere models. The coupling includes the data transfer from one compartment model to the next. This modelling environment enables the repeated calculations of the predefined scenarios needed for uncertainty analysis. The integrated modelling environment will allow the calculation of selected Safety and Performance Indicators.

<u>NEA criteria</u>
The following criteria from the NEA report 3679 will be applied to improve the quality of the safety assessment:

a. sensitivity analyses have been carried out to ensure that scenarios and calculation cases address key uncertainties affecting the performance of the disposal system;
b. mathematical models are based on well-established physical and chemical principles, or on empirical relationships with an experimental basis that supports their applicability in conditions (e.g. scales of space and time) relevant to the assessment;
c. computer codes are developed in the framework of a QA procedure, and verified, for example by comparison with analytical solutions and alternative codes and confidence is increased by means of the simulation of experiments and of natural settings; and
d. a clear strategy and methods exist for the handling of uncertainties.

<u>OPERA research program</u>
In the OPERA research program these criteria will be met as follows:

a. Some sensitivity analyses are foreseen as preparation to the uncertainty analyses in OPERA WP 7.3. These analyses will be used in combination with expert judgment to identify the key uncertainties affecting the performance of the disposal system;
b. OPERA research will provide much of the scientific basis for the assessment models;
c. The organization that maintains the computer code for the integrated model uses a certified QA system including procedure for proper development and maintenance of computer codes.
d. In OPERA WP 7.3 a strategy and methods will be described for the handling of uncertainties.

3.5. Comparison With Assessment Criteria

SSG-23 description

SSG-23 proposes that estimates of doses and risks for very long time periods should be made and compared with appropriate criteria. For facilities such as geological disposal facilities, SSG-23 claims that the likelihood of human intrusion has essentially been eliminated (unstated but likely by appropriate siting criteria) but that the assessment of human intrusion scenarios may be performed to test the robustness of the system.

OPERA implementation

NEA indicators (NEA, 2012) give a more elaborate approach to endpoints and comparison with assessment criteria. This is taken up in the OPERA research program task 7.3, where a list of safety and performance indicators will be established.

NEA criteria

There are no criteria specified in NEA 3679 specific to the assessment criteria. However, the NEA report gives an overview of "evidence, arguments and analyses" that are needed for the safety case that can be applied.

- General evidence for the strength of geological disposal as a waste management option
- Evidence for the intrinsic quality of the site and design
- Safety indicators complementary to dose and risk
- Arguments for the adequacy of the strategy to manage uncertainties and open questions

OPERA Research Program

General evidence is often qualitative knowledge and information about the disposal system that can be used to argue that geological disposal can be safe. This information is usually displayed in the context of the safety case. In the OPERA research program WP 7, safety assessment, there is no task devoted to collecting and formulating this type of evidence. Usually this is done at the synthesis level, not at the research level.

Evidence for the intrinsic quality of the site and design is obtained along the lines of the safety functions and safety and performance indicators dedicated to these safety functions (see e.g. SCK.CEN publications (Marivoet, 2010) and (Weetjens, 2010)). This approach will be taken up in WP 7.3. Safety indicators complementary to dose and risk are also taken up in WP 7.3.

Arguments for the adequacy of the strategy to manage uncertainties and open questions is not a specific task in the OPERA Research Program, but can be taken up at the synthesis level.

4. Conclusion

The Safety Assessment Methodology as described in the OPERA research plan and as implemented in the OPERA research projects has been evaluated against the Safety Assessment Methodologies provided in IAEA SSG-23 (IAEA, 2012) and NEA 3679 (NEA, 2004).

A safety assessment methodology generally consistent with the IAEA's has been chosen and is shown below. NEA criteria (NEA, 2004) are recommended for use in evaluating the application of the safety assessment methodology. The figure below shows the seven steps (slightly modified from IAEA SSG-23) for the safety assessment methodology, as well as related aspects of the OPERA research program.

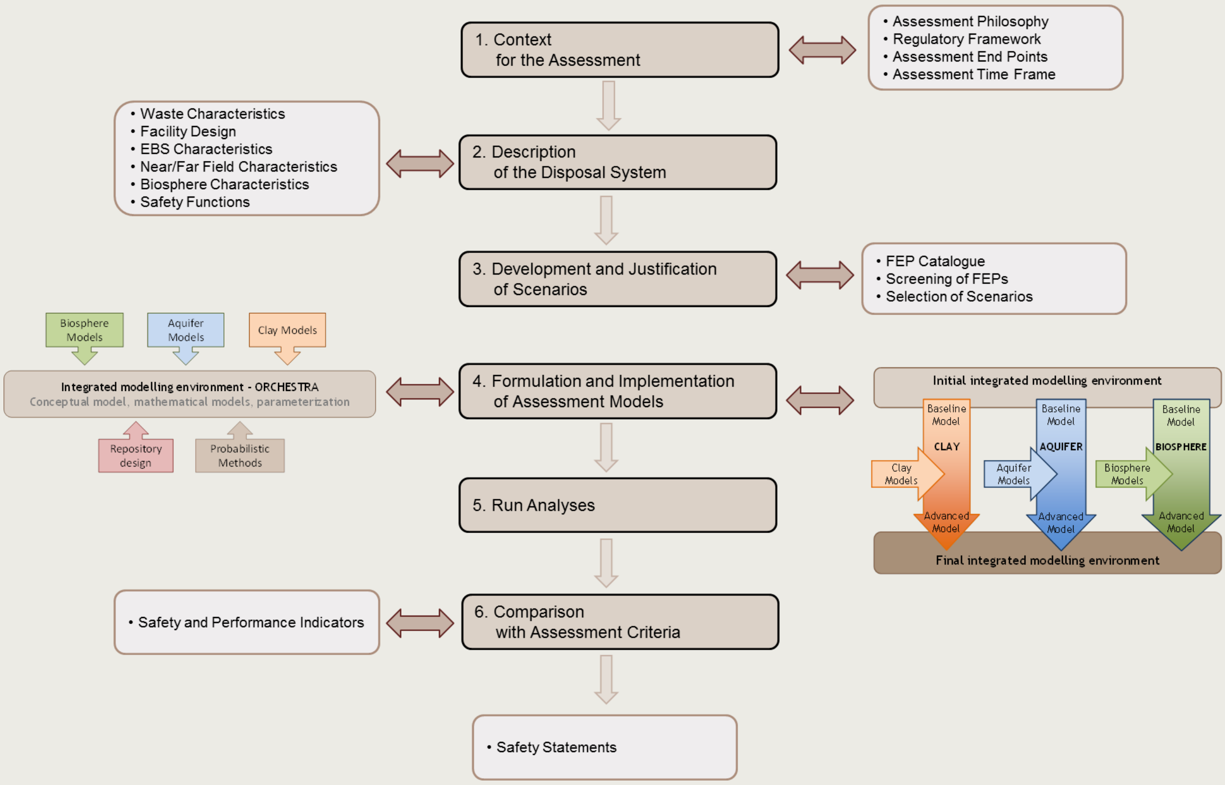

Figure 4-1 The recommended safety assessment methodology for the OPERA project

<u>In summary:</u>

A slightly edited version of the framework provided by IAEA SSG-23 is recommended for use as the OPERA safety assessment methodology. This approach is in line with the ISAM scheme, as presented in the OPERA Research Plan.

For OPERA a 'top-down' method is used for scenario analysis. That is, analyses of how safety functions may be affected by FEPs, followed by a process of auditing the scenarios developed against an international list of features, events and processes.

In OPERA WP 7 an integrated modelling environment is developed and refined, which includes the treatment of uncertainties.

From the NEA reports 3679 and 78121 a list of criteria has been extracted for guiding and evaluating the assessment to improve the quality of the OSC. The OPERA research program allows addressing these criteria in the research activities. However, the extent to which these criteria have been met can only be judged after completion of the research program.

5. References

(IAEA, 2004)

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Appendix 1 IAEA Safety Standards relevant for the OPERA safety assessment

IAEA Safety Standards for protecting people and the environment
Safety Assessment for Facilities and Activities
No. GSR Part 4
General Safety Requirements Part 4

- applies to all nuclear facilities, including disposal facilities
- allows graded approach (can be used as an argument for assessing long term safety only, because actual implementation of disposal in NL is still far away)

Overall requirements

Requirement 2: Scope of the safety assessment
Requirement 3: Responsibility for the safety assessment
Requirement 4: Purpose of the safety assessment

Specific requirements

Requirement 5: Preparation for the safety assessment
Requirement 6: Assessment of the possible radiation risks
Requirement 7: Assessment of safety functions
Requirement 8: Assessment of site characteristics
Requirement 9: Assessment of the provisions for radiation protection
Requirement 10: Assessment of engineering aspects
Requirement 11: Assessment of human factors
Requirement 12: Assessment of safety over the lifetime of a facility or activity

Defence in depth and safety margins

Requirement 13: Assessment of defence in depth Safety analysis
Requirement 14: Scope of the safety analysis

IAEA Safety Standards for protecting people and the environment
Disposal of Radioactive Waste
Specific Safety Requirements
No. SSR-5

SAFETY REQUIREMENTS FOR PLANNING FOR THE DISPOSAL OF RADIOACTIVE WASTE
Governmental, legal and regulatory framework

- Requirement 1: Government responsibilities
- Requirement 2: Responsibilities of the regulatory body
- Requirement 3: Responsibilities of the operator Safety approach
- Requirement 4: Importance of safety in the process of development and operation of a disposal facility
- Requirement 5: Passive means for the safety of the disposal facility
- Requirement 6: Understanding of a disposal facility and confidence in safety Design concepts for safety
- Requirement 7: Multiple safety functions
- Requirement 8: Containment of radioactive waste
- Requirement 9: Isolation of radioactive waste
- Requirement 10: Surveillance and control of passive safety features

REQUIREMENTS FOR THE DEVELOPMENT, OPERATION AND CLOSURE OF A DISPOSAL FACILITY
Framework for disposal of radioactive waste

- Requirement 11: Step by step development and evaluation of disposal facilities

The safety case and safety assessment

- Requirement 12: Preparation, approval and use of the safety case and safety assessment for a disposal facility
- Requirement 13: Scope of the safety case and safety assessment
- Requirement 14: Documentation of the safety case and safety assessment

Steps in the development, operation and closure of a disposal facility

- Requirement 15: Site characterization for a disposal facility
- Requirement 16: Design of a disposal facility
- Requirement 17: Construction of a disposal facility
- Requirement 18: Operation of a disposal facility
- Requirement 19: Closure of a disposal facility

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