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INTERNATIONAL PEER REVIEWS IN THE FIELD OF RADIOACTIVE WASTE
Questionnaire on principles and good practice for safety cases

Over the past two decades the NEA, on behalf of requesting countries, has regularly organised international peer reviews of national safety reports in the field of geological disposal of radioactive waste. The present document is a questionnaire to be distributed to the relevant reviewee at the beginning of the review process. It helps provide a first check on status regarding the current, international collective learning of what is important in a safety case for disposal, with emphasis on safety assessment. The questionnaire is meant to help start the review process in an efficient manner and to provide a common basis to the peer reviews of disposal safety cases organised by the Agency.

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FOREWORD

Peer review as a working method is closely associated with the OECD, where it is facilitated by the homogeneous membership and the high degree of shared trust among the member countries. International peer reviews have been regularly carried out under the aegis of the NEA.

In context of the services that the NEA provides to its member countries, a peer review can be described as the systematic examination and assessment of a national waste management programme or a specific aspect of it, with the ultimate goal of assisting the requesting country to comply with established principles, to adopt international best practices and, in some cases, improve policy. The examination is conducted on a non-adversarial basis. Its quality relies importantly on the mutual trust among the NEA Secretariat, its supervising committee (the RWMC), and the organisation requesting the review, as well as on shared confidence in the process. With these elements in place, peer review tends to create a system of mutual learning and mutual accountability among NEA member organisations. NEA-organised peer reviews are, thus, a method for cooperation and improvement. To date, the NEA has organised over 15 peer reviews of national studies ("safety cases") pertaining to the safe geological disposal of radioactive waste, with a clear acceleration in the past decade. Guidelines on how such NEA-sponsored peer reviews are organised, conducted and documented were published in 2005.

There is high interest to verify, through peer review, the degree of adherence to international best practice. The present questionnaire has been assembled by the NEA Secretariat as one important basis on which peer reviews may perform such verification in studies documenting the safety case for disposal. The questionnaire addresses generic aspects of safety cases that should be common to all such studies, with an emphasis on safety assessment. It draws on the many years of experience by the NEA Secretariat, on the international state-of-the-art and on available literature. The questionnaire is sent to the programme being reviewed at the beginning of a review. The programme's responses help then the review team to understand better the study or safety case under review and its limitations, to consider its standing vis-à-vis international best practice, and to take the review forward with additional questions. This understanding will be enhanced further in the course of the review in discussions within the international review team as well as in face-to-face discussions among the review team and staff from the programme being reviewed.

Acknowledgments

This document updates the original 2005 version of the questionnaire [NEA/RWM/PEER(2005)2] by bringing in aspects raised internationally through June 2010. All updates and improvements are based on suggestions by the NEA Integration Group for the Safety Case.

INTRODUCTION

This questionnaire refers to principles and good practices that promote confidence in the long-term safety case for disposal of long-lived waste in a geologic repository. The safety case is defined in NEA (2004a) as:

> "*...an integration of arguments and evidence that describe, quantify and substantiate the safety, and the level of confidence in the safety, of the geological disposal facility*".

Confidence itself is defined in NEA (1999):

> "*To have confidence is to have reached a positive judgement that a given set of conclusions are well supported*".

In general, a safety case will conclude, explicitly or implicitly, that there is adequate confidence in the possibility of achieving a safe repository to justify a positive decision to proceed to the next stage of planning or implementation. The 2004 NEA Safety Case “brochure” (2004a) makes it clear that this conclusion refers to confidence on the part of the author of the safety case - typically the implementer - based on the analyses and arguments developed and the evidence gathered. The audience of the safety case must decide for itself whether, or to which extent, it believes the reasoning presented is adequate, and whether it shares the confidence of the safety case author. Principles and good practices that, if followed, should promote such confidence relate to:

- achieving an adequate strategy for managing repository planning, implementation and closure,
- achieving a robust system,
- providing an adequate assessment basis (including the assessment capability),
- providing guidance for addressing remaining uncertainties, and
- integrating the analyses and arguments developed and the evidence gathered into a set of conclusions that are adequate to inform and support a positive decision to proceed to the next stage of planning or implementation.

The present questionnaire deals with these different aspects of promoting confidence in the safety case. The questionnaire supports the NEA guidelines outlining the conduct and role of OECD/NEA peer reviews (NEA, 2005).

There exists an international body of knowledge on what constitutes a modern, long-term safety case for geological disposal of radioactive waste. The NEA, notably through the work of its Integration Group for the Safety Case (www.oecd-nea.org/rwm/igsc.html)[1], has largely contributed to defining the international state-of-the-art and continues refining it. It is important that NEA-organised peer reviews make reference to the international state-of-the-art and that there is assurance that generic issues, like those addressed in the present questionnaire, are taken into account in the study under review. Programme-,

1 For specific list of publications the reader may also want to consult the complete list of NEA documents organised by subject at www.oecd-nea.org/rwm. It includes the peer reviews completed to date.

project-, and review-specific issues also exist, of course. They are typically addressed in the Terms of Reference for each requested peer review and constitute another important facet of any peer review.

The present questionnaire is ultimately a checklist to assist future peer reviews in taking into account the key points specifically identified in the NEA Safety Case "brochure" (NEA 2004a) and in the NEA "confidence document" (NEA 1999). It also considers new aspects raised since then in the international scene; in particular in the joint IAEA/NEA standard for deep geologic disposal of high-level radioactive waste of 2006. Specifically, this document updates the original 2005 version of the questionnaire by bringing in aspects raised internationally through June 2010.

THE QUESTIONNAIRE

A number of questions and their rationale are presented hereafter. For each question, the response should:

- indicate whether the items listed have been taken into account in the safety case under review, and
- provide references to where in the documentation of the safety case these items are covered.

A short summary of how the listed items were taken into account would be helpful, but is not necessary.

For an example of the style of responses expected, respondents are referred to Annex 1 of NEA (2004b), which provides the responses to a similar questionnaire in support of the peer review of Project Opalinus Clay.

The list of questions that follows is not intended to be a content guide for a safety case. *It is intended to facilitate a review by having the organization being reviewed respond to it with a reference, for example, to where discussion of a topic can be located. If there is no page reference, the review team knows it is not covered and can ask why it is not. There may be a perfectly legitimate reason for non-coverage or little coverage of a* particular *topic, as discussed above*. Indeed, in an actual peer review, the phase that the requesting organization is working in will determine which topics and questions are emphasized and which are de-emphasized. For example, a waste management programme moving into repository operations may not need to spend much time on describing the site selection process, but should have a very mature understanding of its natural and engineered systems. In contrast, a waste management programme just beginning site characterization would want to describe the features and preliminary investigations of the site that led to its selection, and may have less to say about the details of its engineered barriers.

I. Managing the overall programme

I.1 Programme constraints

A number of factors constrain the way in which the planning and implementation of a repository proceeds. These include programme constraints that apply at all stages of a waste-management programme, as well as practical constraints that apply at a particular stage of development.

Which of the following constraints apply to the current project and where are they described in the project documentation?

a) Various strategic decisions determined at national level (e.g. to pursue, in addition to the domestic option, the possibility of international disposal options, to reprocess or dispose of spent fuel directly, to investigate one or more host rock options, to examine more than one design option, and to implement the repository in stages, beginning with an initial "demonstration repository" for a portion of the waste to be disposed, etc.).

b) Legal requirements (e.g., roles of relevant organisations, transparency laws, and requirements for providing a degree of retrievability in design).

c) Time constraints on repository implementation, which may be affected, for example, by the capacity available for interim storage.

d) The licensing framework requiring a safety case to be made at defined points within the planning and development programme.

e) The regulatory framework, e.g., assessment endpoints and timeframes.

f) Constraints resulting from the implementer's strategy to implement the programme (e.g. the necessity to come to a design decision).

g) Adoption of a stepwise approach to repository planning and implementation.

I.2 Management strategy

According to NEA (1999, 2004a), a management strategy coordinates the various activities required for repository planning, implementation and closure, including siting and design, safety assessment, site and waste form characterisation and R&D. The management strategy keeps work focused on programme goals, allocates resources to particular activities, and ensures that these activities are correctly carried out and co-ordinated.

Are the following technical and managerial principles applied in the programme and, if so, where are they described in the documentation of the safety case? If other principles are adopted, where are those documented?

a) Establishment of a safety culture (i.e. a "consistent and pervading approach to safety") among all those engaged in aspects of repository planning and implementation, including the development of the safety case.

b) Establishment, implementation and maintenance of a quality management system and quality control procedures.

c) Arrangements for ensuring that the implementing organisation has suitably qualified and experienced personnel covering the range of disciplines relevant to the safety case, and a system for training and further education/development of staff.

d) Establishment of clear roles for, and effective lines of communication between, those within the implementing organisation and its supporting organisations – particularly between safety case developers, safety assessors, research scientists, designers/engineers and operations staff.

e) Establishment of clear and effective lines of communication between the implementing and regulatory organisations and other oversight bodies.

f) Establishment of procedures and policies for interaction with other stakeholders.

g) Establishment of means for effective integration of knowledge and information within the safety case.

h) Arrangements for periodic updating and use of the safety case and safety assessment to guide repository development, operation (e.g. waste acceptance), and closure.

i) Arrangements for independent peer review of the safety case and supporting work.

j) Establishment of a strategy for recording, managing and archiving of knowledge and information over the whole project timeframe, so that programme decisions can be placed in a broad, historical context.

II. Principles, guidelines and procedures for developing a safe and robust system

Robust systems are, according to NEA (2004a), characterised by a lack of complex, poorly understood or difficult to characterise features and phenomena, by ease of quality control and an absence of, or relative insensitivity to, detrimental phenomena arising either internally within the repository and host rock, or externally in the form of geological and climatic phenomena. They are also characterised by a lack of uncertainties with the potential to compromise safety. Various principles, guidelines and criteria can be identified that aim to ensure robustness by minimising unfavourable phenomena and uncertainties and/or the effects of uncertainty on the evaluation of safety.

Box 1: (NEA 1999) describes two categories of robustness:

Engineered robustness: Intentional design provisions that provide additional assurance of disposal system performance and safety, in order either to compensate for known phenomena and uncertainties or to guard against the possible consequences of unexpected phenomena, are said to provide "engineered robustness" (e.g. conditioning the waste in highly durable matrices, over-dimensioning of certain engineered barriers).

Intrinsic robustness: Intentional siting provisions that avoid or reduce the effects of potentially detrimental phenomena and sources of uncertainty are said to provide "intrinsic robustness" (e.g., the selection of a site away from natural resources such as oil, gas, minerals etc.).

Were national or internal principles in place regarding the following topics? If so, which of the following were applied, and where is implementation of these described?

a) Inclusion of reserves of safety in the system concept.

b) Adoption of multiple safety provisions, such as the multi-barrier concept or the concept of multiple safety functions, in order to avoid over-dependence on any single safety provision, safety function, or barrier.

c) Adoption of a flexible strategy for design development and improvement (e.g. "design-as-you-go") in order to ensure safe and efficient use of the host rock and repository capacity.

d) Principles relating to optimisation and Best Available Technology (see e.g. NEA 2010).

e) Engineering principles other than those identified in Box 1 above to promote robustness (e.g. the backfilling of access routes, measures to guard against future inadvertent human intrusion, the use of institutional surveillance etc).

f) Other engineering principles for the design, construction and operation of the repository.

Were national or internal guidelines in place regarding the following topics? If so, which of the following were applied, and where is implementation of these described?

a) Guidelines related to the characteristics of a site (e.g. a site that is geologically stable and structurally understandable and/or characterisable with respect to processes and events – including geological events and possible inadvertent human intrusion).

b) Guidelines related to the design basis for the repository (e.g. a minimum depth for the repository; a site may be sought that is larger than the minimum necessary; the possibility for retrievability and monitoring may be incorporated in the design).

c) Safety-related exclusion guidelines for a site and/or for zones within a site (e.g. exclusion zones around geological features with unfavourable properties, regional zones of weakness, etc).

d) Guidelines related to waste conditioning and packaging (e.g. prohibition of liquid waste forms, use of a stable passively safe waste matrix, use of long-lived containers).

e) Guidelines related to the safety of repository construction (e.g. requirements on exploration, drilling, mining and excavation methods to minimise the excavation damaged zone)

f) Guidelines related to the safety of repository operation (e.g. requirements to minimize the presence of certain materials, requirements on waste handling and operational safety, requirements on the locations and methods of emplacement for different waste types).

g) Guidelines related to the safety of repository closure (e.g. requirements on backfilling and sealing).

Which of the following procedures were applied, and where is adherence to these procedures described?

a) Procedures for peer review (e.g. of decisions regarding siting and repository design, and of the safety case and safety assessment).

b) Quality assurance procedures for waste and site characterisation, waste immobilisation and container fabrication, repository construction and operation.

c) Quality assurance procedures for waste acceptance.

d) Quality assurance procedures for safety case and safety assessment.

III. Assessing system safety and robustness

The means that are available to assess the safety and robustness of a disposal system are collectively termed the assessment capability. The assessment capability should be used to generate an assessment of adequate quality and reliability. According to NEA (1999), the assessment capability comprises:

- The identification and conceptualisation of safety-relevant features, events and processes (FEPs), their evolution over time and their possible interactions.
- The identification and development of appropriate assessment models and couplings amongst models, the compilation of the required data and model parameters in form of discrete values or sets of values, or probability density functions (PDFs), and the implementation of the models, normally in the form of computer codes.
- A critical reflection on the uncertainties in the understanding of the FEPs, models and the associated data.
- The uses of thorough quality management to assure a proper and reliable application of the assessment methodology, models, data and codes in a safety assessment.

III.1 The assessment methodology

Do the following apply to the assessment methodology used in the current safety case and, if so, where are they described?

a) Definition and characterisation of the initial state, including an assessment of the uncertainties in the initial state.

b) Identification of the safety functions of the main system components.

c) A strategy for classifying and handling the different classes of uncertainty (e.g., scenario uncertainty, model uncertainty and parameter uncertainty).

d) Identification of a broad range of scenarios that encompass the possible evolutions of the disposal system.

e) Identification of a range of scenarios (or cases) for quantitative evaluation in safety assessment; this may be more limited than the range referred to in (d).

f) Use and justification of stylised treatments for certain scenarios or FEPs (e.g. for human intrusion, for the biosphere) where there are uncertainties that are, in practice, impossible to quantify or reduce.

g) Identification of the most important features and processes on which the safety functions rely at any particular stage.

h) Emphasis and analysis in the safety case of the most important features and processes in order to assess the robustness of the disposal concept.

i) Identification of the most important safety-relevant parameters (e.g. through sensitivity and uncertainty analyses).

j) Creation of 'frozen' versions of the safety case and the underlying database in order to make its assessment during review and evolution during subsequent updates traceable.

k) Checks for overall and internal consistency of assumptions, models, and supporting data.

l) Formulation of conceptual models that are based on sound science and engineering, and that are supported by evidence.

m) Consideration of alternative conceptual models.

n) Identification of whether assumptions, models, simplifications, and parameter values are realistic, reasonable, conservative or otherwise, and an analysis of how collectively these choices affect the results of the safety assessment.

o) Consideration of alternative performance indicators (e.g. relating to engineered barrier performance; relating to water flows and radionuclide fluxes) to complement dose and risk estimates.

III.2 Identification of safety functions and FEPs

To what extent are the safety functions and FEPs considered based on the following? Where is this documented?

a) Scientific knowledge (e.g., of processes) and technical experience (e.g. of materials behaviour), as supported by literature (including literature related to anthropogenic and natural analogues, and theoretical and experimental evidence from inside and outside the radioactive waste field).

b) Structured approaches to repository design and description (e.g. by using "Interaction Matrices" or "Process Influence Diagrams" to represent processes and interactions between different elements of the system).

c) Measures to ensure comprehensiveness of the FEPs considered and the relationships between FEPs and the fulfilment of safety functions (e.g. by comparison with international databases).

d) A reasoned definition of the time-scales over which safety assessments and the supporting modelling are carried out, and over which the safety functions need to be fulfilled.

III.3 Development of assessment models and databases

To what extent are the assessment models and parameter values that support the current safety case based on the following? Where is this documented?

a) Expert elicitation and expert judgement.

b) Scientific and technical literature (theoretical and experimental evidence from inside and outside the radioactive waste management field).

c) Small-scale experiments (e.g. on the properties and behaviour of repository materials).

d) Studies of relevant (similar) natural systems and natural analogues.

e) Underground rock laboratory (URL) studies.

f) Large-scale site-specific field studies (e.g. pumping tests, tracer tests).

g) Process models for extrapolation to repository conditions and scales.

III.4 Ensuring proper application of the assessment methodology, models, data and codes

Have the following been applied to ensure proper application of the assessment methodology, models, data and codes that support the safety case. If so, where is this described?

a) Quality assurance procedures for the safety assessment.

b) Peer-review of the safety assessment methodology, models, data and codes.

c) Verification of the assessment codes (e.g. through comparison with analytical solutions and with results from other codes).

d) Examination of the performance of the assessment codes and supporting models when applied to similar problems (e.g. the use of groundwater flow models to simulate behaviour observed in field tests).

e) Comparison of the assessment data and parameter values with information from other sources (e.g. alternative data in the literature, data used in other safety assessments, data held in international databases).

f) Checks to determine compliance with any requirements for statistical convergence of model results.

g) An analysis of the results from the safety assessment to demonstrate that they are in accordance with the general understanding of the behaviour of the disposal system that has been modelled (e.g. through expert judgement and possibly by the use of more simplified models of the most important safety related processes).

III.5 Assessment results

For each scenario evaluated in the current safety case which of the following apply? Where c), d) or e) apply, what if any arguments are made to counter these unfavourable conclusions? Where are these arguments documented?

a) Assessed consequences are below (or within) acceptance guidelines across the range of model and parameter uncertainty.

b) Assessed consequences at or above acceptance limits have been identified, but the likelihood of such a scenario is argued to be low.

c) Assessed consequences at or above acceptance limits have been identified, but the consequences are not related to the evolution of the repository itself but, rather, to significant externally-imposed

FEPs (such as large meteorite impact or nuclear war). In such cases, releases from the repository may not dominate the overall consequences to human health, and some might be regarded as force majeure.

d) Assessed consequences at or above acceptance limits have been identified; the likelihood of such a scenario is not known at present.

e) Assessed consequences at or above acceptance limits have been identified and the likelihood of such consequences is judged to be significant.

IV. Implementation, planning and feasibility

Does the safety case include information relating to aspects of repository implementation, planning and engineering feasibility? Which of the following topics are addressed, and where is this described?

a) Identification and selection of materials for repository components (e.g. waste containers, buffers, backfills and seals).

b) Supply, quality assurance and characterisation of engineered barrier materials.

c) Methods for engineered barrier component manufacture (e.g. waste containers, buffer and backfill blocks, repository seal components).

d) Trials and demonstrations of engineering feasibility (e.g. covering excavation and tunnelling to required tolerances; waste packaging, handling, and emplacement; engineered barrier emplacement).

e) Approaches to quality compliance checking and testing of manufactured components.

f) Plans for quality compliance checking and monitoring of installed components

g) Plans for waste and engineered barrier emplacement, including methods, sequences and timings.

V. Arguing the case to proceed to the next development stage

A safety case that concludes that there is sufficient confidence to justify a positive decision to proceed to the next stage of planning or implementation must provide adequate support for this conclusion.

The focus of the safety case has generally been on argumentation that the consequences (or risks) have been thoroughly assessed and are acceptable vis-à-vis the acceptance guidelines. Other complementary lines of argument are, however, also required in order to show, for example, that an appropriate site-selection process has been followed, that systematic approaches have been applied in disposal concept and repository design, that the waste and the site have been well characterised and are sufficiently well understood, and that a programme of work is in place to manage remaining uncertainties. In recent years increasing attention is being given to issues associated with implementation, feasibility, uncertainty management.

Which of the following are explicitly cited as complementary evidence or lines of argument to support the final conclusions or recommendations of the safety case? Where are such arguments documented?

a) That appropriate management systems are in place to proceed to the next step in the repository development programme in a safe and secure manner.

b) That the relevant principles, guidelines and procedures have been adhered to in order to achieve a safe and robust system.

c) That there is sufficient confidence in the understanding of the site and the disposal concept, and that a strategy is in place for addressing and managing uncertainties[2].

d) That there is sufficient confidence in the assessment capability and the assessment basis, and in plans for research and development work to manage and reduce uncertainties.

e) That plans for implementation of the disposal concept are feasible and have been, or will be, tested, demonstrated and verified.

f) That explicit connections have been identified between safety and the roles (safety functions) of the various barriers within the multi-barrier concept.

g) That sufficient knowledge exists that provides confidence that the barriers will perform as intended and fulfil their functions.

h) That all identified safety-related issues that are important for the decision under consideration at the current development stage have been addressed.

i) That there are FEPs that would contribute to safety, but which have not been included in the quantitative safety assessment.

j) That consideration has been given to all relevant data and information, together with their associated uncertainties.

k) That all models and databases used have been adequately tested.

l) That a well-defined and rational assessment procedure has been used, and the effects of uncertainties on the conclusions of the assessment considered.

m) That the safety case and safety assessment have been fully disclosed and subjected to quality assurance and peer review.

n) The existence of independent evidence, obtained, for example, by comparing assessment results with independent studies performed for similar disposal concepts (in particular, the results of sensitivity analyses within these studies).

o) Other evidence and lines of argument.

2 According to both NEA (1999) and NEA (2004a), a key element of the safety case is the guidance that it provides for addressing uncertainties and remaining siting and design issues in the course of future programme stages. Uncertainties can be reduced by research investment, or else they can be avoided or their impact can be reduced through siting and design measures.

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