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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

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Integration Group for the Safety Case (IGSC)

PROCEEDINGS ON SAFETY CASE

IGSC Topical Session held 25th November 2001, Paris-France.

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FOREWORD

In recent years, it has become more and more evident that repository development will involve a number of stages punctuated by interdependent decisions on whether and how to move to the next stage. These decisions require a clear and traceable presentation of technical arguments that will help in giving confidence in the feasibility and safety of the proposed concept. The depth of understanding and technical information available to support decisions will vary from step to step. A Safety Case is a key item to support the decision to move to the next stage in repository development.

In that frame, a Topical Session focused on the **"Safety Case**" was organised in the framework of the 3rd meeting of the IGSC (Integration Group for the Safety Case). This session was held in Paris in France on the 25th November 2001.

50 participants represented several national waste management organisations, regulatory authorities, from 15 OECD member's countries, IAEA and EC.

The items covered in the presentations concerned the studies with respect to the recent results from safety assessments and peer reviews for the deep disposal of radioactive waste.

This Topical Session showed the importance of the future work to do on that topic. Moreover, the presentations showed the need to provide a safety brochure that will describe the issues connected to the Safety Case and the approaches available for satisfying the four elements of a Safety Case. It will not imply that all techniques and approaches be used in every safety case. Rather, it would provide a sense of the problems that exist and the range of techniques and approaches that can be used to formulate the Safety Case and develop and communicate confidence.

The paper summarises the lessons learnt within some focused organisation studies as they evolved over the course of a decade and now allow a comprehensive view of what constitutes a safety case.

ACKNOWLEDGEMENT

The NEA expresses its gratitude to:

- Gérald Ouzounian (ANDRA, France) who chaired the Topical Session;
- Patrik O'Sullivan (NPG, Netherlands) who co-chaired the Topical Session as a rapporteur;
- The speakers for their interesting and stimulating presentations as well as for their written contributions.
- The IGSC participants for their constructive contribution.

Patrik O'Sullivan and Sylvie Voinis (NEA secretariat) have prepared the proceedings, which was reviewed by Gérald Ouzounian and Abe van Luik, as chairman of the IGSC.

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PART A
SYNTHESIS

1. INTRODUCTION

It is accepted universally that an assessment of the safety of proposed geological repositories is a key input to the decision-making process regarding the development of these facilities. Accordingly, implementing and regulatory organisations in many of the OECD/NEA countries are involved in the investigation and resolution of issues associated with repository safety and NEA has been concerned with this issue for several years.

Most current repository development programmes envisage that repository development will occur in an incremental fashion, with decisions being taken by national authorities at several steps in the development process. It may be envisaged that safety assessments will become progressively more refined at successive stages of the development process, with an expectation of increasing levels of confidence that the assessed levels of safety can be realised in practice.

Different countries are at different stages and therefore opinions can be expected to vary on where the key issues remain.

In accordance with current terminology the Safety Case for a proposed facility should present the results of the safety assessment together with an illustration of the level of confidence in the results. The safety case should also discuss how levels of uncertainty would be reduced in succeeding development phases.

Over the years, insights were obtained from the activities of the working group IPAG[1] and other groups with NEA, and from reviews of national safety studies conducted by regulatory authorities and others. The establishment of the IGSC[2], to bring together all activities relating to the safety case, recognised its key role of the latter in the process of repository development. Initiatives currently being pursued by the IGSC include the development of a "Safety Case Brochure", to synthesise current understanding about the requirements of the Safety Case. The IGSC has a role to develop common views on such key aspects of the Safety Case but should not be prescriptive. Therefore, since the beginning of the IGSC, two meetings were organised with topical sessions. The following major messages emerge from these exchanges:

- Multiple lines of reasoning should include additional safety measures and indicators;
- It is not possible to rigorously demonstrate compliance; the only realistic objective is to achieve adequate confidence;
- The way in which different bodies of scientific opinion are dealt with in the Safety Case is an important and outstanding issue;
- Whether, for example, operational safety is included in the Safety Case will depend on the particular circumstances of the Member countries;
- Development of the Safety Case involves mediation with society;

1 The Working Group on Integrated Performance Assessments of Deep Repositories
2 The Integration Group for the Safety Case

- We should take a common sense definition of the Safety Case and not make it more complicated than it needs to be;
- It is a presentation and linking of information and arguments on safety needed to support the decision-making process;
- Dependent on the programme-specific and regulatory context, the implications of retrievability may need to be dealt with in the safety case;

To go further in establishments of the safety case brochure, a "Topical Session" on the Safety Case was organised as part of the 3rd plenary meeting of the IGSC. This session took place in Paris, France, on 25th November 2001 and was attended by 50 participants representing several waste management organisations and regulatory authorities from 15 OECD member countries, the IAEA and the European Commission.

The Topical session was mainly aimed at exchanging information on:

- National programmes where safety assessments are currently being undertaken or have recently been completed, e.g. ONDRAF/NIRAS, NAGRA and ANDRA;
- Feedback from peer reviews, e.g. SR97 (Sweden) and the Yucca Mountain biosphere assessment
- The evolution of ICRP recommendations including the assessment of human intrusion;
- Future activities, in particular launching the initiative to develop the safety case brochure [see NEA/RWM (2001) 4].

The Chairman of the Topical Session was Gérald Ouzounian (ANDRA, France). The rapporteur was Patrick O'Sullivan (NRG, Netherlands).

This document presents the various presentations and exchanges that took place during the Topical Session. Part A of this document summarises the material presented and provides a short overview of the main outcomes. The papers presented are compiled without elaboration by the Secretariat as Part B of the document and Part C gives a complete list of participants. It is hoped that the document as a whole provides a synthesis of current issues in safety case development including key issues being identified in recently undertaken peer reviews.

All overheads from the Topical Session are available by request from the NEA Secretariat.

2. BACKGROUND

The concept of a "safety case" has been progressively clarified in a series of initiatives that the NEA has had in the past decade, and which culminated with the publication of the NEA confidence document [NEA 1999] and the latest IPAG exercise [NEA 2001]:

> "*Safety Case: A Safety Case is a collection of arguments at a given stage of repository development, in support of the long-term safety of the repository. A Safety Case comprises the findings of a safety assessment and a statement of confidence in these findings. It should acknowledge the existence of any unresolved issues and provide guidance for work to resolve these issues in future development stages.*"

Generally, the Safety Case is considered as one of the key bases and needs thus to be structured, technically argued, and supported with a clear link to the step-wise decision-making process and the level of confidence must reflect commitments at each relevant step. An articulation and contents of four main processes are proposed in the NEA confidence document (see figure hereafter) that need to be achieved is proposed in a view of permitting safety to be argued and assessed by decision makers such as regulators, scientific bodies, and/or others:

(i) Establish an ASSESSMENT BASIS
- define a *safety strategy* that describes a suitable approach to the building of a safety case
- define the repository site and design (*system concept*)
- define the *assessment capability*

(ii) Carry out a PERFORMANCE ASSESSMENT
- evaluate repository performance for the assessment cases
- assess compliance with acceptance guidelines
- carry out sensitivity analyses

(iii) EVALUATE CONFIDENCE in the calculated safety and modify, if necessary the assessment basis

Steps (i), (ii) and (iii) define the safety assessment.

(iv) Compile a SAFETY CASE
- document the safety assessment
- state confidence in the safety indicated by the assessment and describe proposed way forward

Interact with decision makers and modify, if necessary, the assessment basis

Over the years, insights were obtained from the activities of the working group IPAG, that started in 1994 and consisted of three phases, with the aim to provide an international platform to examine the overall status of Safety Cases and their supporting Integrated Performance Assessment (IPA) studies and to confirm by practical examples the ideas. Through the successive IPAG exercises, *Traceability*[3] and *Transparency*[4] were considered as relevant issues in PA even though they consume time and resources. Some guidance on methods for promoting transparency is given such as the presentation of assumptions and their basis, describing data used and their sources, demonstrating the accuracy of modeling, and explaining the results and points of weakness. According to the Safety Assessment report, participants agreed that a universal plan of contents couldn't be recommended. One key aspect of developing traceability and understanding between the implementer and regulator is consistency of the methods and documentation structure and style. Other, non-technical stakeholders also review IPAs and have different needs with regard to traceability and transparency. An integration of their viewpoints is needed. However, taking account of the need to promote transparency in PA documents, a set of fourteen elements (or topics) that should be addressed in a safety assessment report was proposed. Four of those elements were the Objectives and scope of the assessment, the Approach to safety assessment, a detailed Description of the disposal system, and the basis for Confidence in key arguments.

Moreover, *Uncertainty* regarding phenomena and data over time scales such as the future course of events external to the repository or the long-term evolution of engineered materials were emphasized as an important issue in the Safety Case. Consequently, the need for a clear strategy for dealing with these uncertainties will be explained within the Safety Case and its supporting IPA. Generally, the higher the margins of safety in barrier performance, the less stringent are the demands on the precision of associated data. The quality of the Research and Development (e.g., site characterisation, properties of materials involved…), procedures, data and the use of these data are crucial and must be clearly stated in a dedicated section of the IPA's documentation.

IPAs should address the issues of uncertainties (on scenarios, models and parameters) and completeness in the context of the safety arguments and relevant characteristics of the specific disposal system. Finally, natural analogues are seen as a component of the confidence-building process as they support the understanding of key processes regarding the different components of the multi-barrier system and provide evidence that no unexpected processes or phenomena have been present or active.

The IPAG-2 study that compared international experiences of peer reviews of IPAs pointed up the necessary integration of site investigation and design development in the PAs, focusing on the intrinsic safety of the disposal system and not only on the calculations used to demonstrate safety. Multiple lines of reasoning such as natural analogues and paleohydrogeology might help in this objective and a variety of techniques and approaches could be used in a complementary manner, e.g., probabilistic versus deterministic calculations. In addition, qualitative "soft" and quantitative "hard" information should be considered as complementary arguments and as already indicated in the IPAG-1 report, consideration should be given to increasing their value in the decision-making process. At the end, the multi-barrier system was confirmed as the key element for long-term safety and clearly needs to be emphasized as such by the implementers.

In IPAG-3, the objectives were to evaluate the state-of-the-art for obtaining, presenting and demonstrating confidence in long-term safety, and to make recommendations on future directions and initiatives for improving confidence. As already mentioned in the previous IPAG exercises, the long duration of the process reflects the complexity of the tasks and the desire to proceed by cautious steps

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3 By traceability, it was understood as an unambiguous and complete record of the decisions and assumptions made, and of the models and data used in arriving at a given set of results.

4 By transparency, it was understood as the PA record to be written in such a way that its readers can gain **a** clear picture, of what has been done, what the results are and why they are as they are.

due to technical issues and social acceptance. Based on answers provided by IPAG-3, key arguments were identified in order to get confidence in the proposed Disposal System, the Data and Knowledge of the Disposal System, the Assessment Approach, IPA Models and in the Safety Case and the IPA Analyses.

Moreover, IPAG-3 participants confirmed the various ideas of the previous exercises, particularly that the assessment and modelling approaches must also be clear, logical, continually improved through an iterative process, and submitted to independent peer reviews and accepted by stakeholders. For getting confidence in the modelling, one solution might consist of verification of numerical modelling by comparison with simple analytical models, solution of test problems and comparison of results from different methods used to resolve the same problems.

Regarding the confidence statement, it should explain clearly how the assessment results compare with the appropriate regulatory criteria, and could also make comparisons with levels of naturally occurring radiation and other everyday risks, to put the radiological risks arising from a repository into perspective.

At least, the peer reviews are also considered as a relevant activity both on methodologies and major R&D studies in order to provide a decision-making basis for moving from one step to another. Peer Reviewers want to see more of a Safety Case than a Safety or Performance Assessment. Vis-à-vis a Safety Assessment/Performance Assessment, a Safety Case places the analyses and information in a decision-making context and shows strategic thinking and management strategy. They generally mention that the programme needs to be performed in a way that favours dialogue with stakeholders: technical community, regulators, and local community. The previous peer reviews generally show that:

- Safety Assessments are limited and demonstrate assessment capability or likely or actual compliance with the “regulatory requirement”;
- The geology is normally well described, but more data are needed;
- Engineered barrier systems need to be emphasised in that they offer, at early stages, margins for optimisation and adaptation to the local environment;
- The role and use of experts is an important issue in building confidence;
- Less technical sections do exist but are not accessible to non-specialists. Lots of details exist with little rationale for choices/decisions, e.g., role of scenarios, role of biosphere representations, data;
- Lessons are being generated for subsequent assessments or repository development phases, but this feedback is not evident;
- Reasons for confidence in the analyses are interspersed in the documentation. No drawing together in conclusions on the quality of what was done and perspective on what more may be done;
- Common finding is thus that these studies have important limitations as tools for:
  - informing decisions on what to do next;
  - dialogue amongst interested parties;
  - arguing safety.

Typical problem areas are identified such as:

- Completeness of scenario analysis;
- Consistency needs to be improved in assumptions, the level of detail, the vocabulary;
- The transitory phase needs more attention;
- Issues of traceability and transparency.

As a conclusion, the Safety Case is a management issue. Feedback to each relevant part of the Safety Case such as design and site characterisation can be possible if it is planned and managed at each relevant step of the repository development. As regards this last point, it is suggested that it is perhaps an area where further work could be done. Achieving safety in a calculation is not sufficient to get confidence in the safety case. One key task is to provide relevant arguments on the confidence in the safety. These arguments must be declared and described in the Safety Case. A confidence statement should describe the strength of the arguments on which the findings of the safety assessment are based. For instance, in order to better support the confidence statement, it is important to offer commentaries on (i) the role of barriers and system functions, (ii) the identification and explanation of the assessment cases, (iii) the verification of the quality of tools, data, analyses, and the explanation that PA is for testing system performance.

3. SUMMARY OF PRESENTATIONS

The session began with an introduction by Gerald Ouzounian (ANDRA, France); who said the safety case involved the integration of information at two different levels. At the first level this involved the integration of knowledge about the site and the wastes with information concerning the disposal design concepts. By this means the basic information need to model the phenomena occurring during the various phases of the system evolution would be available. The second phase of integration was concerned with how the system worked. It involved integration of the simulations determined during the first phase with scenarios representing the future evolution of the disposal system. The performance assessment involved the modelling of the postulated scenarios.

Lucy Bailey (Nirex Ltd, UK) presented the conclusions of the third phase of the work undertaken by IPAG[5] - the IPAG-3 project concerned with approaches and arguments to establish and communicate confidence in safety and in the overall results of Integrated Performance Assessments (IPAs). The project involved the collation of experiences on approaches to confidence building from 20 organisations and the final report includes examples illustrating confidence in the overall safety case, including confidence in the disposal concept, the data, modelling and performance assessments, including the interaction between site characterisation, design and performance assessment. It was noted that there is a clear trend towards developing overall strategies for managing uncertainties in a safety case.

Peter de Preter (NIRAS/ONDRAF, Belgium) provided an overview of the Belgian programme of research and development on deep disposal. The planned submission in December 2001 of SAFIR 2 (the second Safety Assessment and Feasibility Interim Report) would mark an important milestone, as the report would inform a decision by the Belgian government on the nature of future research. An independent committee of scientists established by NIRAS/ONDRAF had reviewed a draft version of the report. The committee was generally in agreement with the technical R&D priorities proposed in the report but suggested that there should be more integration of technical and societal aspects. The committee also recommended that a future research programme should compare the option of deep disposal with other strategies for long-term management of radioactive wastes. It was suggested that a strategic environmental assessment might provide an appropriate mechanism for comparing alternative management strategies, and would enable societal dimensions also to be addressed.

Piet Zuidema (Nagra, Switzerland) described the development of the safety case for a high level waste repository in Opalinus clay in which canisters would be placed in large vaults. The current phase of work was concerned with demonstrating the feasibility of the disposal concept. The Safety Case is taken to mean a set of arguments to support a statement that the proposed facility will meet relevant safety criteria and will include arguments giving the basis for confidence that those arguments are correct and properly taking account of uncertainties. The safety strategy was concerned both with the inherent robustness of the disposal concept and the adequacy of the assessment capability. As regards the former, the arguments being advanced were primarily qualitative. Key issues in terms of the documentation of the Safety Case were traceability and transparency of information, including how to ensure that key arguments did not become obscured because of the need to make available very large quantities of information.

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Michel de Franco (ANDRA, France) described plans to report its first safety assessment of facility designs for disposal of high and intermediate level waste and spent fuel. This assessment will be the forerunner of a more detailed assessment that is required to be presented to the French government in 2005 and is intended to facilitate the formalisation and testing of the assessment methodology intended to be used in the 2005 assessment report. The report will include information about the waste inventory, the materials used for the engineered barriers and current understanding of the geology and surface environment at the Bure site in eastern France. It will also describe the preliminary design concepts and the phenomena defining the evolution of the repository in different timeframes as well as presenting the results of the initial performance assessment of the repository. The report will also include an analysis of the implications of the requirement for reversibility, taken to mean that each repository development step can be reversed.

Allan Hedin (SKB, Sweden) described recent reviews of SR’97 by a NEA review team and by the Swedish regulatory authorities, SKI and SKB. The NEA review team concluded that KBS-3 was a sound disposal concept and that SR 97 provided a sensible illustration of the potential safety of that concept. On that basis SKB’s desire to move to a site selection phase was well founded. It was suggested that there should in future be more frequent, iterative, safety assessments and it would be preferable if more formal scenario selection techniques were used. The regulatory authorities also found that the KBS-3 concept was soundly based but indicated that an exhaustive analysis of the concept would be required in due course taking account of information from site investigations and testing of the proposed engineered barriers. They were generally satisfied with the assessment methodologies described in SR-97, though some deficiencies were identified with regard to scenario development, the methodology for probabilistic calculations, methods for feedback to site investigation and design and the programme for future assessments.

Abe van Luik (USDOE-YM, USA) presented the preliminary results of the Yucca Mountain international peer review of the Total System performance Assessments (TSPA) and a few preliminary indications of the issues. The peer review by 10 experts was organised by a joint secretariat formed by the NEA and the IAEA. Two meetings and three exchanges of questions and answers by email between the meetings provided preliminary results that were orally presented at the end of August. The final report is due to the DOE by the end of January 2002. Abe Van Luik presented some unofficial examples of preliminary observations. As an example, he mentioned the reviewers’ observation that uncertainties need an overall strategy for their evaluation and reduction. It was also mentioned that the documentation is not yet sufficiently transparent. An important issue for the review team was the ability to compare the safety evaluations of different nations' potential repositories. Finally, the reviewers made it clear that although the applicable regulation for this phase had been competently addressed, the documentation was not a safety case. Several shortcomings kept it from being a safety case, noteworthy being the lack of a statement on confidence, and a description of the basis of that confidence.

Alan Hooper (Nirex Ltd, UK) proposed an outline for a ‘safety brochure’ intended to provide a comprehensible description of a Safety Case for geological disposal and thereby help to build confidence that a competent and ethical approach was being followed to support decision making. The brochure would identify the key elements of a Safety Case in terms of safety objectives, safety functions of barriers required to achieve those objectives, the evaluation of the reliability of those safety functions and the approach to the resolution of uncertainties. The brochure would also describe the iterative development of the safety case, including how the concept is tested, the role of feedback, how progress is documented and the role of regulation.

Jean-Claude Nénot (IPSN, France) gave an overview of recommendations from ICRP during the past 25 years that are relevant to the safety of waste disposal. These recommendations were primarily concerned with public exposure, and suggested that the necessary system of protection should be controlled through the principles of constrained optimisation and prescriptive limits. The principles of justification, optimisation and dose and risk limitation were applicable to waste management. Justification should however be applied to the practice resulting in the generation of waste rather than to waste management per se. As regards optimisation, this should be interpreted in a subtler manner than the simple application of cost-benefit analysis, as an aggregation of very small doses over future world populations would be essentially meaningless. The primary criterion should therefore be the dose to an individual from a relevant critical group, and optimisation should also take account of social and economic factors. The application of dose limits had intrinsic difficulties because of multiple sources, through restrictions determined as a result of monitoring could be envisaged. The approach to dealing with potential future intrusion presented a particular difficulty (as compared to natural processes) because the probability of occurrence could not realistically be determined and therefore a risk-based approach was not recommended. Instead, prospective doses should be assessed against criteria for intervention situations, as proposed in ICRP 82, i.e. action (in terms of a preventative design change, for example) was unlikely to be justifiable at hypothetical and uncertain future dose levels below about 10 mSv/year.

Conclusion

It is evident that the meaning of the term “safety case” has evolved significantly since the establishment of IPAG in 1994, from initially being essentially synonymous with the IPA to now being a presentation of evidence, analyses and lines of reasoning relating to long-term safety, including a statement of confidence in the findings of the IPA. In the context of a staged repository development process the evolving Safety Case will provide a basis for decisions about subsequent stages of the development process. An implication of the changing nature of a Safety Case is an increased emphasis on qualitative arguments relating to the inherent robustness of the disposal concept and the understanding of how the elements of the disposal system evolve and interact over time.

The requirement to apply the principle of optimisation of protection, and the need for transparency and traceability of arguments, is leading to a need for more discussion of the reasoning behind design and other decisions, which in turn may require discussions of the range of options considered. In a similar vein it may be appropriate to discuss explicitly potential impacts and the measures being taken to avoid or mitigate those having potentially significant consequences. These developments are leading to an increasing overlap between issues addressed in the Safety Case and those covered by the environmental impact assessment. It is clear that the implications of these overlaps are now being considered in a number of programmes.

An important current issue in several countries is how to enable the integration of the technical and societal considerations relevant to safety and acceptability of disposal systems. It was noted that a step-wise process of repository development would be helpful in enabling the public to make inputs throughout the repository development process. The process of environmental impact assessment required before development consent is granted may provide a useful mechanism for facilitating this dialogue process. The potential benefits of hearings were also mentioned in this regard.

The issue of how to address requirements for transparency and traceability are being addressed in a number of programmes. It is evident that, unless addressed carefully, there is the potential for these requirements to be in conflict, as the large volume of information involved to provide traceability could obscure the transparency of arguments. The need for implementers to present a clear line of argumentation to help the public understand was emphasised during the session. Implementers should also have a clear strategy for managing uncertainties and for building increased confidence in the safety of the disposal system and in the assessment methods as repository development proceeds. There was a strong view also on the importance of the early involvement of the regulatory authorities in the repository development process.

The session heard presentations on reviews of performance analyses conducted in Belgium, Sweden and the USA and it was evident that there are a number of common themes. As regards design aspects a key current focus is on practical considerations such as direct demonstration of engineered barrier systems in underground research laboratories. On the issue of safety assessment the need for more formalised techniques for scenario development was evident to assure comprehensiveness, the treatment or management of uncertainties requires a high-level approach, and there is still a need to enhance and systematise feedback between site investigations, design activities, and performance assessment.

Using the NEA confidence document as a starting point, the IGSC will continue the work on the definition of processes, components, methodology and means of ensuing consistency which are required to build a safety case.

PART B
COMPILATION OF THE PRESENTATIONS

(Please note that the overheads of the presentations are available on request at the NEA secretariat)

INTEGRATION TO THE SAFETY CASE

Gerald Ouzounian
ANDRA, France

The Safety Case is considered as a major tool for decisions by playing an important role in the dialogue amongst the various audiences that need to be engaged at each stage of the step-wise process of the repository. In that frame, one relevant issue for the Safety Case is the integration of all technical, design, strategy data and objectives in order to provide a comprehensible Safety Case that will increase the confidence in the project.

Moreover, the Safety Case comprises the findings of the safety assessment and a statement of confidence in the findings including a statement of confidence in the data that are used in this assessment. As a consequence, the Safety Case will acknowledge the existence of the unresolved issues and thus provide guidance for work to involve in the next stage of the step-wise process.

The first level of the integration work concerns the input of the scientific and design data such as:

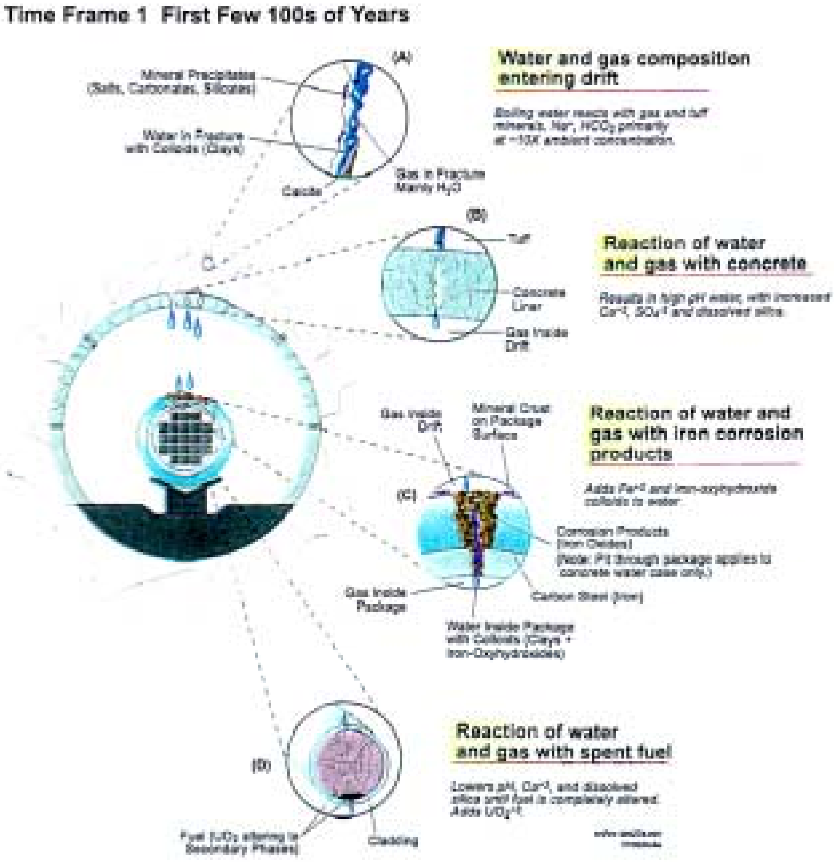
- The characteristics of the host formation e.g geology , past present and future, hydrogeological and chemical properties;
- The characteristics of the waste package e.g the chemical and radioactive inventory, characteristics of the packages;
- The description of the disposal design concept.

From these informations, an additional work consists of the development of a consistent understanding of the site and the THMCR (thermal, hydrological, mechanical, chemical and radiological) interactions. However, in order to describe correctly how the disposal system works over more than several decades' periods, there is a need to split the time and the space into consistency and successive phases. Specific phenomena and processes will be described for each time frame and thus, the integration work will consist of an overall description within the uncertainty regarding the various processes in consistency with the time and space frame considered.

As an example, the figure 1 shows the processes considered during the time frame related to the first few 100s of Years.

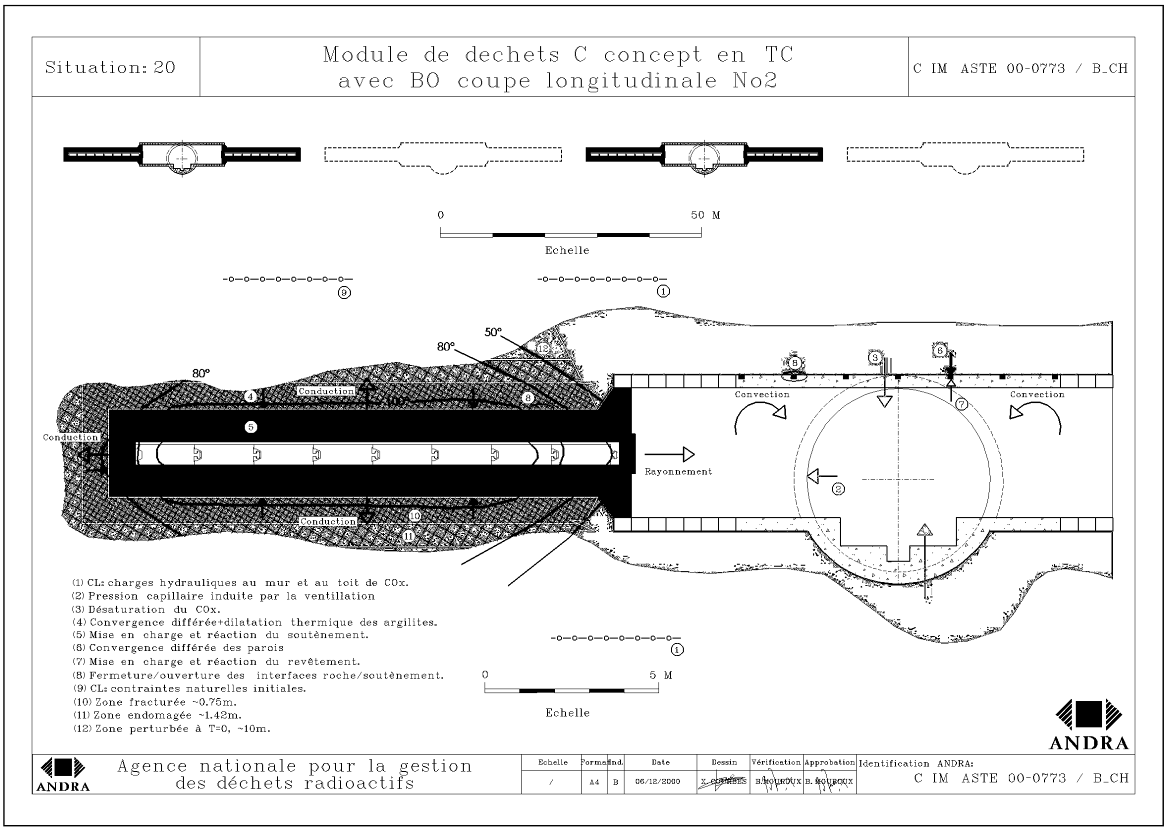
Figure 1. **Examples of Processes related to the first 100s of Years at Yucca Mountain (YM)**

Example at YM



The figure 2 then shows the way to describe the THMC processes regarding a waste package into a drift.

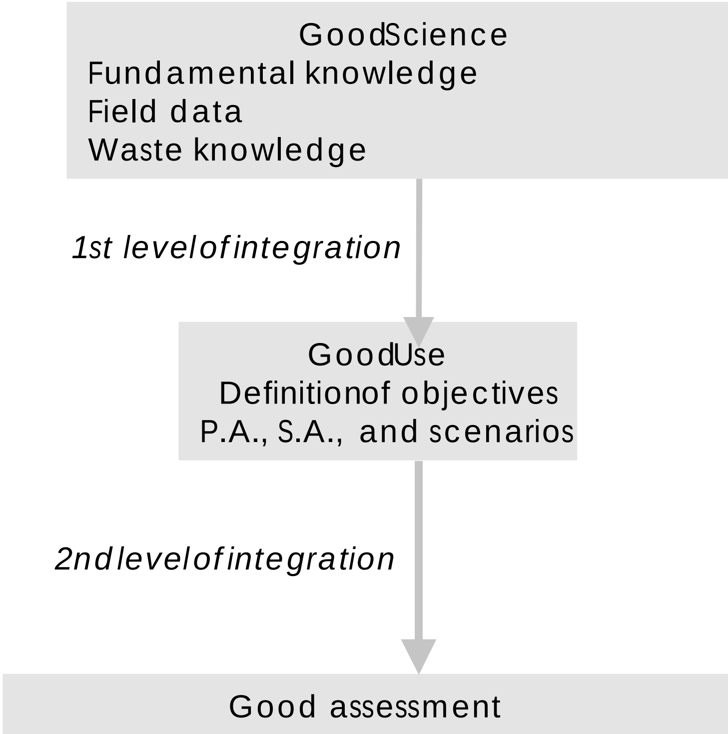
Figure 2. **THMC processes regarding a waste package into a drift**



Such a description allows a detailed analysis of the system at each stage. However, a second level of integration is needed in order to understand and describe how the system works at a large scale and to perform the safety assessments. This integration requires selecting the relevant phenomena according to the objective of the demonstration: that consists of the development of the scenarios. Another dimension of the integration could also deal with the simplification of the system by using relevant parameters. For instance, most of the time, based on initial thermodynamical data or environmental properties, the description of the chemical process will consist of using some “simple” parameters such as the solubility limits or the Kd (representing the sorption process).

As a conclusion and shown into the figure 3, the two levels of integration will allow to go from a good science to a good use and then a good assessment. The management of these information as well as the two levels of integration are necessary to increase the confidence in the Safety Case all over the various stages of the step wise process.

Figure 3. **Levels of integration**



EXTRACT OF THE [NEA/RWM/IPAG(2001)1/REV] IPAG-3 FINAL REPORT

The NEA Performance Assessment Advisory Group[1] (PAAG) set up the Working Group on Integrated Performance Assessments of Deep Repositories (IPAG) in 1994. The overall aim of the IPAG is to provide a forum for informed discussion on safety and performance assessment (PA), and to examine the overall status of Safety Cases and their supporting integrated performance assessment (IPA) studies. The work is carried out in several phases where the membership and tasks of the group change between phases.

In the first phase [NEA 1997], the goal was to examine recently completed IPAs as a practical body of evidence that would indicate the current status of PA and could shed light on possible improvements for future studies. In the second phase [NEA, 2000-a], the goal was to examine the experience of peer reviews of IPAs, and especially reviews performed in support of regulatory assessment, from both the implementer and regulator points of view.

The third exercise, named IPAG-3, is documented in this report. IPAG-3 was carried out mainly between June 1999 and November 2000. The group evaluated the approaches and arguments that have been used to establish and communicate confidence in safety and the overall results of IPAs. The objectives of IPAG-3 were to evaluate the state-of-the-art for obtaining, presenting and demonstrating confidence in long-term safety, and make recommendations on future directions and initiatives for improving confidence. Twenty national organisations participated in Phase 3, where each had either carried out or reviewed a recent Safety Case or IPA. As in the previous phases, a questionnaire was used to focus the discussion.

The main text describes the findings of IPAG-3 with regard to (i) setting the stage for making confidence arguments, and (ii) developing and documenting confidence arguments. The report also presents some final considerations including a comparison of the findings of IPAG-3 with those from previous phases and other NEA initiatives [NEA, 1999]. The IPAG-3 questionnaire and a compilation of the answers to the questionnaire are provided in appendices to this report. Summary observations and recommendations from IPAG-3 are presented below. Where recommendations are made, these are addressed primarily to organisations carrying out or reviewing Safety Cases and IPAs.

The development of a deep geologic repository is characterised by several stages within a step-wise repository development process and, overall, requires several decades for completion. The long duration of this process reflects the novelty and complexity of the tasks of elaborating a repository concept as well as the sensitivity of such projects in society, and the desire to proceed by cautious steps with due regard to technical issues and social acceptance. At the end of each development stage a decision is taken whether to move forward, and whether the requirements for the next development stage need to be adjusted. It is important to communicate, for each development

1 The PAAG and SEDE were replaced by the NEA Integration Group for the Safety Case (IGSC) in 2000

stage, the basis for the current level of confidence, and clearly indicate the strategy for resolving the outstanding issues.

Generally, the Safety Case is one of the key bases for making decisions regarding the development of geologic repositories. The Safety Case as proposed in the NEA Confidence Document [NEA, 1999] " *is a collection of arguments at a given stage of repository development, in support of the long-term safety of the repository. A Safety Case comprises the findings of a safety assessment and a statement of confidence in these findings. It should acknowledge the existence of any unresolved issues and provide guidance for work to resolve these issues in future development stages*."

Detailed analyses of the long-term performance of the repository, in the form of model calculations, are normally presented in an IPA and form the core of the Safety Case. The Safety Case should state its purpose, be well argued and supported and place itself into context by identifying how it contributes to the decision-making process.

Arguments are required to build confidence in both the intrinsic safety of the disposal system and the assessment of the long-term performance of the disposal system. A variety of confidence arguments should be used to help build and communicate confidence to both technical reviewers and other stakeholders. The key confidence arguments identified in IPAG-3 are presented in chapter 3 of this report and summarised in the table below.

Category	Arguments
Confidence in the Proposed Disposal System	• Intrinsic robustness of the multi-barrier system • "What if?" scenarios and calculations • Comparisons with familiar examples and natural analogues
Confidence in the Data and Knowledge of the Disposal System	• Quality of the research programme and site investigations • Quality assurance procedures • Data from a variety of sources and methods of acquisition • Use of formal data tracking techniques
Confidence in the Assessment Approach	• Logical, clear, systematic assessment approach • Assessment conducted within an auditable framework • Building understanding through an iterative approach • Independent peer review of approach
Confidence in the IPA Models	• Explaining why results are intuitive • Consideration of alternative conceptual models and modelling approaches – simple and complex • Testing of models against experiments and observations of nature • Model comparison exercises • Comparisons with natural analogues • Independent evidence such as paleohydrogeological information
Confidence in the Safety Case and the IPA Analyses	• Clear statements and justifications of assumptions • Demonstrate that assumptions are representative or conservative • Sensitivity studies • Clear strategy for managing and handling uncertainty • Multiple safety indicators • Multiple lines of reasoning

Category	Arguments
Confidence via Feedback to Design and Site Characterisation	• Support for any disposal concept design changes • Overall quality and safety of the disposal system

A multi-barrier system is common to all disposal systems represented within IPAG, however its exact definition can vary from country to country. IPAG-3 recommends that implementers clearly define what is meant by the multi-barrier concept in their Safety Case, including any functional requirements required for long-term safety. Typically, assessments of the adequacy of the proposed multi-barrier system constitute a major portion of an IPA.

At the highest level, the main challenge for any Safety Case and its supporting IPA is addressing the inevitable uncertainties that arise from the long time scales associated with repository performance. It is necessary in an IPA to address such uncertainties in a comprehensive manner and show that, based on the available data and information and accounting for uncertainties, the repository can be expected to provide for the long-term protection of human health and the environment.

Confidence in data employed in the Safety Case rests on the assurance that the research and site characterisation work has been properly carried out and the data correctly understood and interpreted within the performance assessment. A suitable quality control system should be in place giving the ability to track data from its source to its use in the Safety Case and IPA. The assessment approach is also a key part of the Safety Case, and it needs to be clear and transparent in order to build confidence. IPAG-3 recommends that key assumptions and their justifications be clearly stated within a dedicated section of the Safety Case or IPA documentation. The IPA should clearly state the basis for confidence in the models used and the results obtained. In particular, the IPA needs to assess and discuss the sensitivities of safety and system performance to data, model and scenario uncertainties, and explain why the IPA results are appropriate for decision making.

IPAG-3 recommends that a Safety Case should include a clearly developed “confidence statement”, as proposed in NEA [1999], and that this should be given a prominent location within the documentation. Such a statement could, for example, be supported by a review of the approach to managing and handling uncertainty, citing the most important conservative assumptions made and their impacts, and highlighting any “reserves of safety”, such as positive features or processes that were not included in the analyses. The confidence statement should explain clearly how the assessment results compare with the appropriate regulatory criteria, and could also make comparisons with levels of naturally occurring radiation and other everyday risks, to put the radiological risks arising from the repository into perspective.

Overall, the IPAG-3 experience and that of earlier exercises shows a definite trend towards programmes looking at an overall strategy for obtaining and communicating confidence. The further development of these strategies for managing uncertainties and building confidence in long-term safety will be an important item of work for the IGSC. Practical insight will be obtained from the reviews of ongoing and future Safety Cases and IPAs.

SAFIR-2 AND THE BELGIAN METHODOLOGICAL R&D PROGRAMME ON DEEP DISPOSAL

Peter de Preter
ONDRAF/NIRAS, Belgium

1. Background

Safety Assessment and Feasibility Interim Report [SAFIR]

In Belgium, the Radioactive Waste Management Agency NIRAS/ONDRAF is considering the deep disposal of high level and long-lived radioactive waste in clay media.

SAFIR (1989) deals with the first phase of the methodological R&D programme in a view of establishing and increasing confidence in deep disposal. In 1990, the SAFIR Evaluation Commission stated that the focus of the programme on vitrified waste and on the Boom Clay in the vicinity of the Mol/Dessel nuclear zone was justified.

However, the Commission suggested additional issues to consider in the next phase of the programme such as an alternative host formation, the Ypres Clays and the consideration of direct disposal of spent fuel. It also provided the basis for the 1990-2000 R&D programme.

SAFIR-2 reports therefore the results of this ten-years R&D programme in a view of obtaining the governmental decision to continue the technical disposal programme and opening a public debate with the various stakeholders on the long term waste management.

Belgium regulatory framework

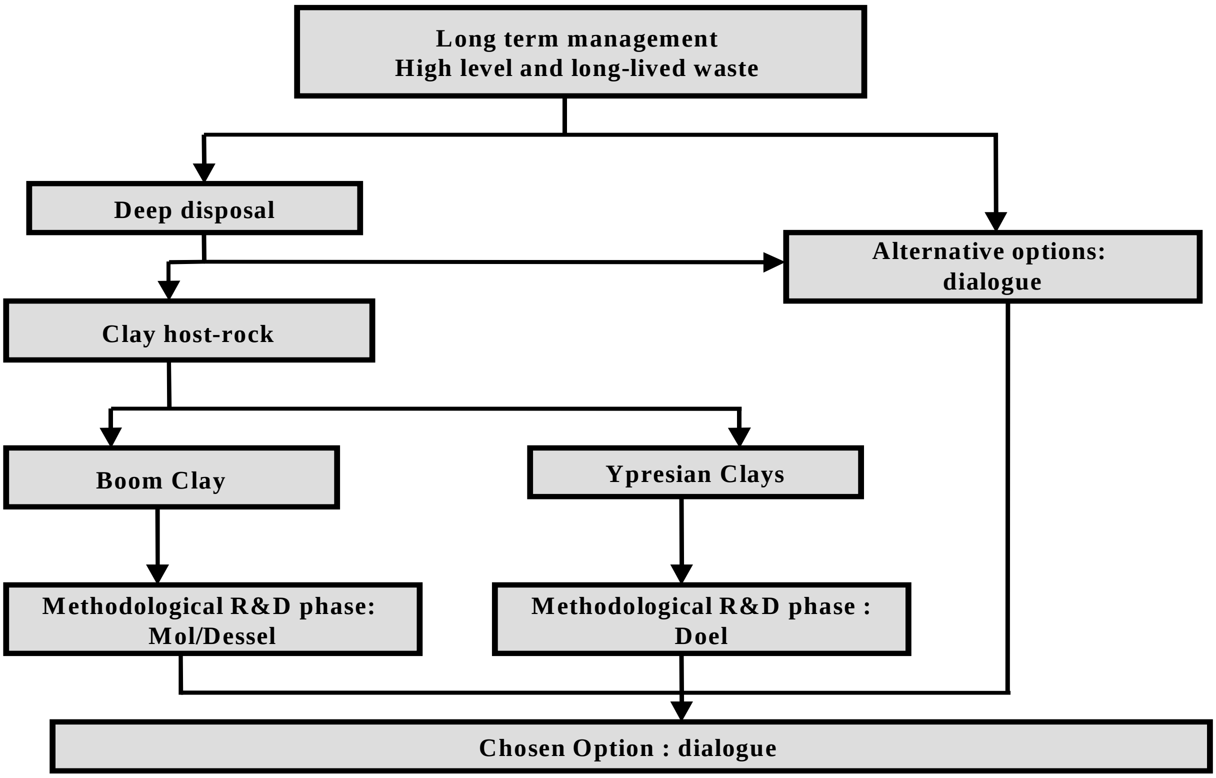
At current time, no specific nuclear regulations for deep disposal exist. As the repository is considered as another nuclear facility, it depends on the “classical “ nuclear and/or radioprotection regulatory guidelines. For instance, the dose constraint is generally set at a fraction of the dose limit of 1 mSv/year. ONDRAF/NIRAS henceforth follows the international ICRP[1] reference texts and the European directives. Additionally, relevant times will extend far into the future, as long the radiotoxicity associated with the repository represents a hazard to human health and the environment. Although retrievability is considered as an important aspect of the programme, there is at this moment no specific legal requirement on it. The repository must also fulfil “classical” environmental regulations (EIA).

1 ICRP: The International Commission for Radiological Protection

2. Objectives

One of the main objectives of SAFIR-2 according to the methodological R&D programme is to establish whether one safe and feasible deep disposal solution exists in Belgium without prejudging the implementation site. The status in the methodological R&D of the various host formations/site in Belgium is: (i) the Boom Clay as the reference host formation within the reference site Mol/Dessel nuclear zone and (ii) the Ypresian Clays as the alternative host formation beneath the Doel nuclear zone as the alternative site.

The figure 1 hereafter shows the successive steps of the process in order to open the dialogue on the chosen option.



One prime factor in SAFIR-2 is to reinforce the scientific and technical foundations of the deep disposal. Within the step-wise process, SAFIR-2 does not intend to provide a status on all the topics to be considered for deep disposal (e.g all type of waste, operational and long-term safety.). It focuses on the feasibility of the disposal system according to the following issues:

- The reference host rock will be considered as the key barrier;
- The vitrified HLW and spent fuel will be studied;
- The interactions between the various components will be considered;
- No priority will be given to the disposal operations and the associated operational safety.

3. SAFIR-2 and its review

As mentioned previously, SAFIR-2 aims to inform the authorities on the technical and scientific aspects of disposal of HLW in poorly indurate clay such as the Boom Clay. In the framework of the step-wise process that is necessary to build confidence in the project; it provides the basis for future exchanges with the regulators as well as a technical support for dialogue with the various stakeholders.

At the moment (October 2001) the draft is internally available as a support for the review by a national scientific committee, which was finished in July 2001. The committee was created by ONDRAF's Board of Directors and consisted of mostly academic Belgian experts. The resulting final version will be available early 2002. Three levels of publication are foreseen: a technical overview report of 200 pages, the main report (1500 pages) and a 20-page brochure.

The committee generally agreed with the technical R&D priorities proposed in the SAFIR 2 report, but recommended additionally that integration of technical and societal aspects should be a priority of the next phase of the programme. The committee also recommended that a future research programme should compare the option of deep disposal with other strategies for long-term management of radioactive wastes. It was suggested that a strategic environmental assessment might provide an appropriate tool for comparing alternative management strategies, and would enable societal dimensions also to be addressed.

Finally, the committee formulated recommendations for the technical R&D priorities, such as a better definition of the source term and the control, of its characteristics (inventory).

In the final version ONDRAF will take into account these recommendations. Some difficulties related to the functioning of the committee have been identified, such the mass of data and information to be discussed, the complexity and multidisciplinary of the subject, the way to deal with long term safety and robustness, the basic sciences approach versus the development of a project.

4. Key issues and recommendations for further R&D

As indicated before, one of the objectives of SAFIR2 is to emphasise the key issues for building confidence in the deep disposal and make recommendations for each of these key issues.

Host formation

The host formation plays a key role in the multi barrier system. The favourable properties for the host formation are the diffusion-controlled transport of solutes, the high sorption capacity; the geochemical conditions and the high geochemical and mechanical buffering capacity to maintain these favourable properties over a long period of time.

However, for assessing and improving confidence in the long-term safety, it is important to ensure:

- An adequate understanding of the migration processes that currently occur;
- An evaluation of the stability of the favourable conditions, in particular the roles of discontinuities on flow and the transport and the long-term evolution of the geochemical conditions in the clay;

- The manner in which the properties and geochemical conditions in the host rock are affected by the THMC induced perturbations into the repository (iv) and a better integration of geoscientific views.

Design

The description and justification of the design bases chosen in consistency with the various constraints are keys issues in the confidence building. The future programme must focus on practical aspects (feasibility issues, direct demonstration). As regards the overpack, the importance of understanding the durability/corrosion processes is emphasised. Also, the approach focusing on “corrosion resistance” must evolve to a “corrosion prevention approach”. The future programme on repository design must be extended to all types of wastes. The report underlines the need for further research on compatibility aspects; mainly for the bitumized waste and the gas production versus the design responses.

Retrievability and monitoring will need further attention in the future works.

Safety Assessment

The Safety Assessment is a key part of the report and gathers the knowledge built up during the period 1990-2000. However some studies need to be performed at the next phase of the stepwise process. For instance, considering the scenario analysis, the alterated evolutions such as the global warming, the human intrusions need to be developed. The report also underlines the need to improve the uncertainty analysis and the use of alternative safety and performances indicators. The transparency on codes, uncertainties and data sources is also seen as a key issue for building confidence in the safety assessment.

The problem on the possible transferability of the methodological R&D to the Ypresian was also highlighted in particular regarding the safety and feasibility issues. Finally, knowledge management is considered as a key issue of an efficient programme and for transfers of the information over the long time.

5. Proposed way forward

SAFIR-2 is one step in the overall step-wise process for a repository in Belgium. Further development of the characterisation, assessment and implementation methodologies will be carried out focussing on the reference host formation and site. Additionally, the PRACLAY demonstration experiment (1995 to 2015) is seen as a transition towards a pre-project phase. This pre-project would start around 2017 and will be formation and site specific. The first Safety Case report that will be based on the PRACLAY design options is planned by 2010. The 2nd iteration of a Safety Case will integrate the results of PRACLAY. It will support the decision to enter a site-specific pre-project phase. This second iteration will be around 2017.

Finally, the integration of the technical and societal dimensions will to be based on the principles of sustainable management of waste, on a broad dialogue, on a continuous R&D programme and on a strategic environmental impact assessment.

THE SAFETY CASE FOR A HLW REPOSITORY IN OPALINUS CLAY: AIMS, METHODOLOGY, FIRST RESULTS

Piet Zuidema
Nagra, Switzerland

This presentation covers the *current status of a safety report* that is still under development and will be submitted to the authorities towards the end of 2002. Therefore, all results are still of preliminary nature.

The safety report is part of the *step-wise approach* chosen in Switzerland. The aim of the current safety report is:

- to discuss the level of safety that is available for the chosen system;
- to indicate that a "good system" has been identified and to compile corresponding arguments;
- to indicate the flexibility available to modify the system according to future findings;
- to discuss the "way forward" from the PA point of view (e.g. possible enhancement of understanding, improvement of system).

To fulfil these aims, the term "*safety case"* provides a suitable framework, using the following definition:

> "The Safety Case is the set of arguments used to support the statement that a repository will meet all relevant safety standards. It generally includes a series of documents which describe the performance, present the evidence used to give confidence in the conclusions of the performance assessment and discuss the significance of any uncertainties or open questions".

The Safety Case has to be seen in context with other factors that contribute to *decision-making* in the step-wise approach of repository implementation:

- the implementation strategy (RD+D, site selection & characterisation, repository design);
- the importance of societal confidence in, and the support of the concept of geological disposal;
- an adequate decision-making process ("who does decide what at what time", public involvement, ...).

For the study underway the *aims and requirements* are thus:

Fulfil overall aims:

- to make the quality of the system visible and to discuss the measures taken to achieve a good system;
- to quantify expected system performance;
- to give guidance to further development (e.g. measures to increase robustness).

Ensure explicit treatment of uncertainties by defining rules for all people involved in the study (achieve adequate "working-culture"). For this purpose, the following questions are essential:

- have all relevant uncertainties been identified?
- have the interactions been properly recognised?
- has the effect of uncertainty been adequately analysed?
- have the necessary counter-measures been taken to avoid uncertainties or to mitigate their effects on system performance?

Ensure a balanced and unbiased assessment of all the information available:

- get input by all relevant groups participating in the programme (has nothing been overlooked? is the information correctly described?);
- eliminate all personal biases (as far as possible) to get a neutral evaluation.

For developing the safety case, a *methodology* has been developed. The methodology is designed to produce a Safety Case that is:

- transparent, in that the arguments and analyses that make up the Safety Case are readily understood;
- complete, in that all reasonably foreseeable possibilities for the characteristics and evolution of the repository system are considered in developing the arguments (including a discussion of bias introduced);
- robust, in that the arguments for safety are reliable and not undermined by uncertainties that give rise to the range of possibilities of repository evolution and performance.

With this methodology, a set of *"Safety Case Arguments"* (lines of evidence contributing to the safety case) is identified and corresponding activities to develop these arguments (broad tasks to construct the safety case) are defined (see Figure 1). The procedures (including the iterative approach) to develop the arguments are depicted in Figure 2.

The sequence of activities for developing the arguments is as follows:

- identify disposal principles;
- choose the disposal system;
- determine what is known / unknown about the system and its evolution (the system concept);
- describe how the system is expected to provide (demonstrable) safety (the safety concept);
- illustrate radiological consequences across the range of uncertainty: define a broad range of cases and analyse them;
- compile the arguments and provide guidance for future stages.

An important result of this process (one of the “Safety Case Arguments”) is the *safety concept*. The safety concept is developed by analysing the contributions of different phenomena to the safety functions of 'retention/decay' and 'lowering of concentration' or dispersion (see Figure 3). For this purpose, the visualisation of the distribution of radionuclides (or radiotoxicity: RTI) in the system provides valuable insight (see Figures 4 and 5). The development of the system (and of the understanding of its behaviour) and the development of the safety concept is done in an iterative manner.

In a next step, the reliability (and the possibilities for alternative evolutions) of the different phenomena contributing to the safety functions is evaluated. With the use of influence diagrams insight is provided on which parts of the system may be affected by the different phenomena (see Figure 6). Considering the existing uncertainties, *alternative system evolutions* are postulated. This leads to a spectrum of cases (see table in Figure 7) which are then analysed and discussed to assess the performance of the system.

For the quantitative analyses of the different cases *models* are needed. Specific measures are taken to ensure that the models and data are appropriate and correctly used (Nagra QA system). When applying the models, in some cases deliberate conservative bias is introduced where uncertainties are unavoidable and/or irreducible and to address model and data limitations.

The preliminary quantitative *analyses* of the broad spectrum of cases show for all cases low calculated doses (reference cases: see Draft Figure 8).

The dose calculations are complemented with *supporting evidence*; an example is the concentration profiles of environmental isotopes depicted in Figure 9.

Figure 1. **Lines of evidence in the Safety Case for the proposed SF / HLW / ILW repository and the broad tasks to develop these lines of evidence and construct the safety case. Colours indicate which lines of evidence are linked to particular broad tasks**

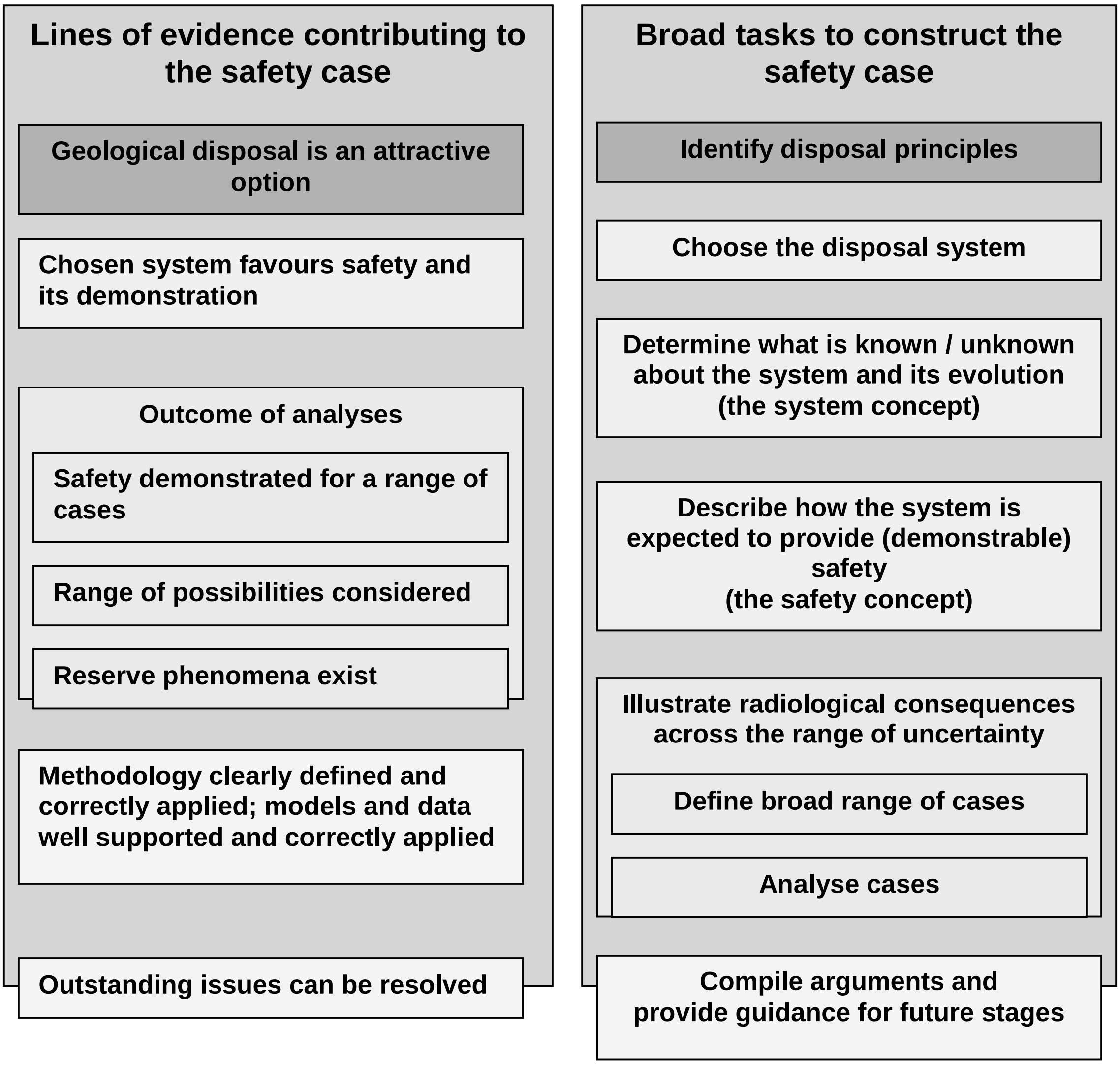


Figure 2. **The procedure for constructing the safety case**

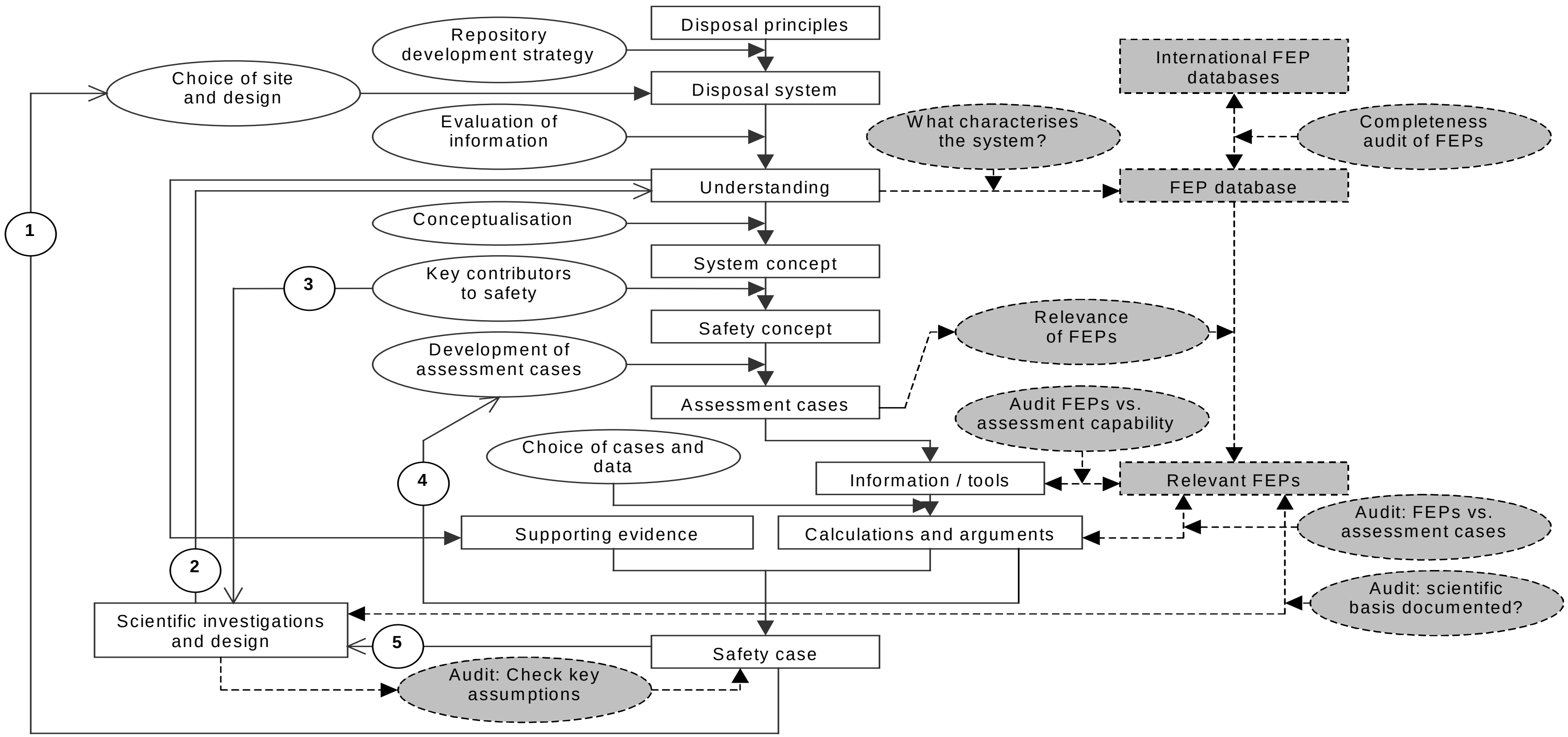


Figure 3. **Schematic illustration of the process of developing the safety concept.**

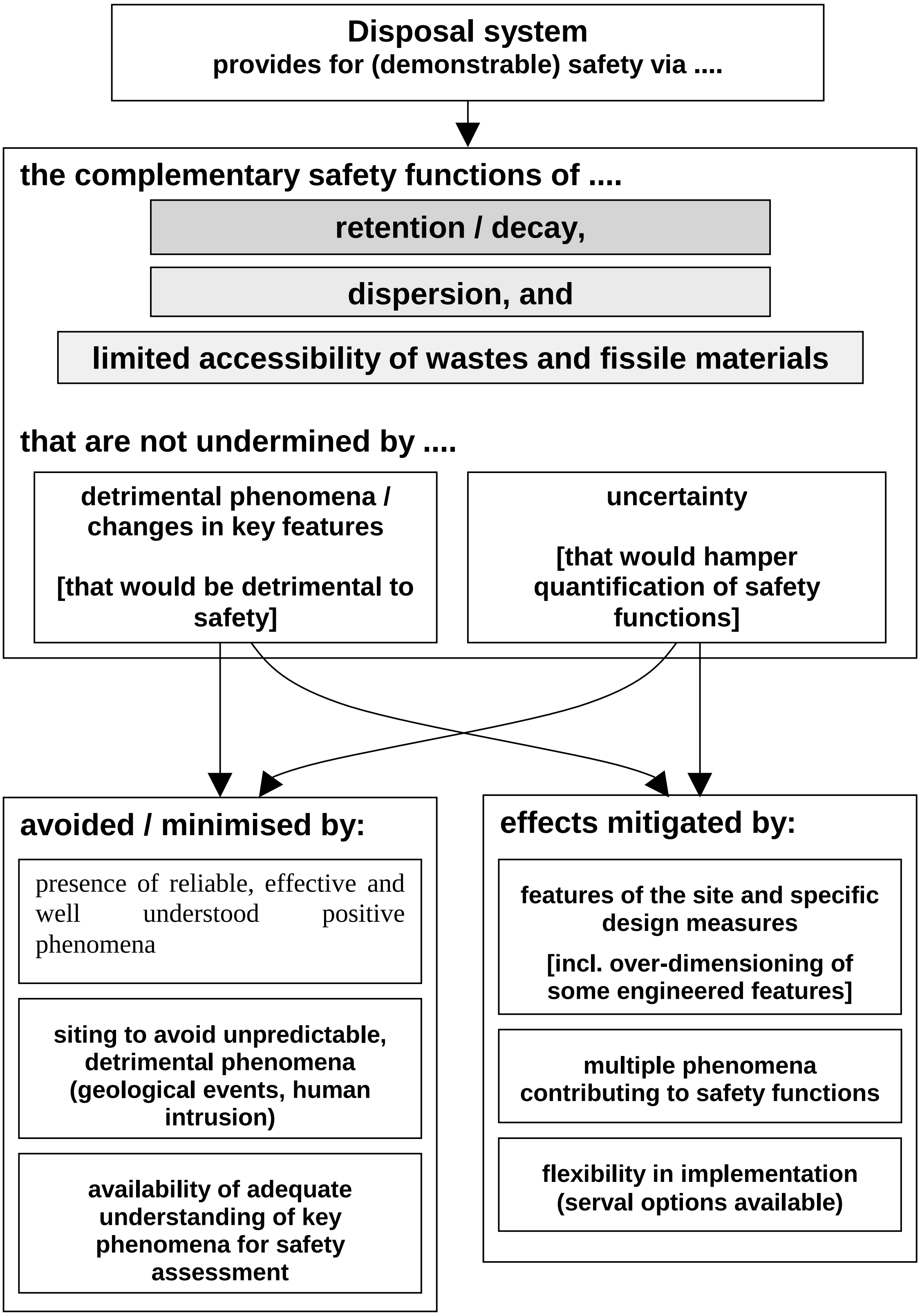
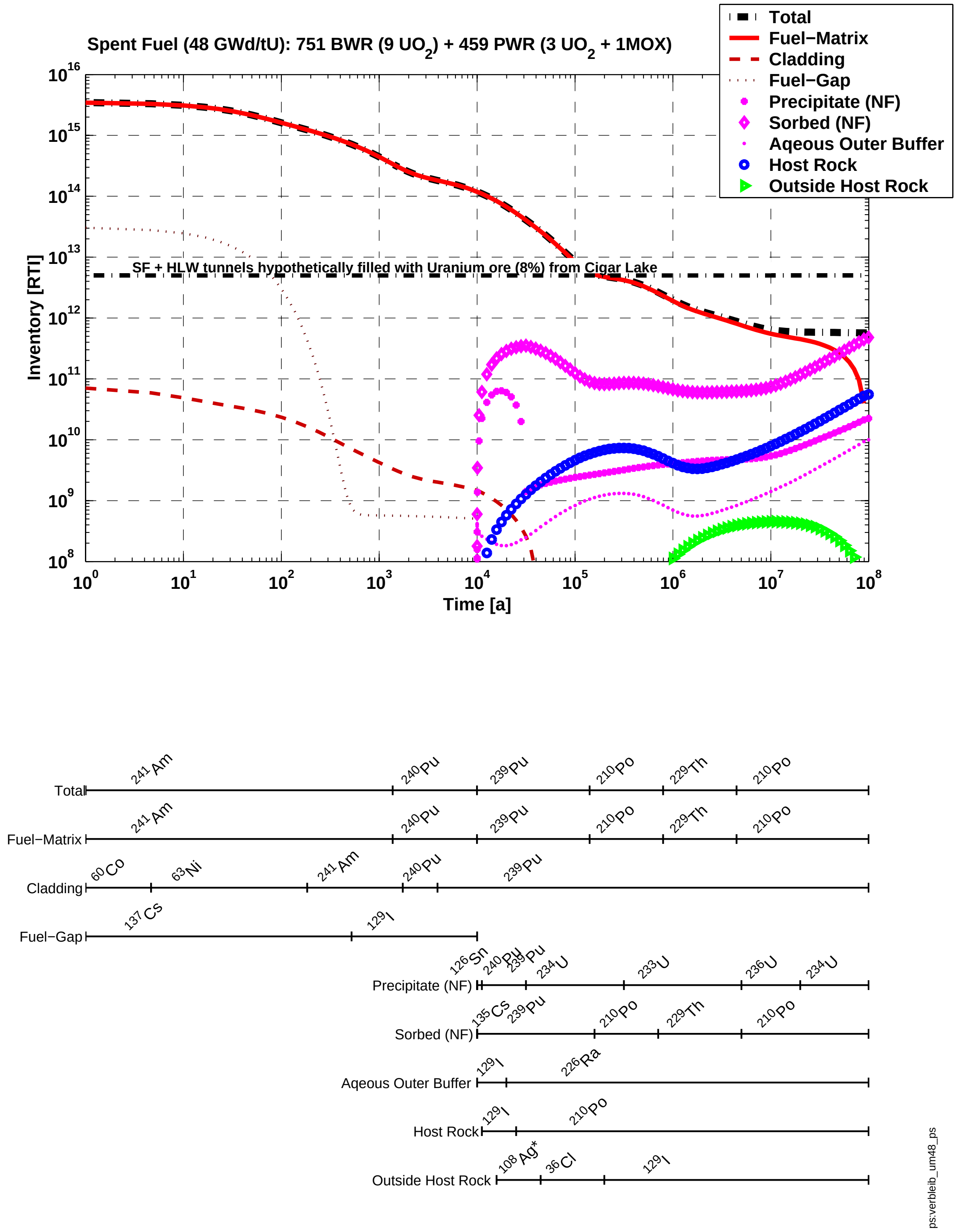
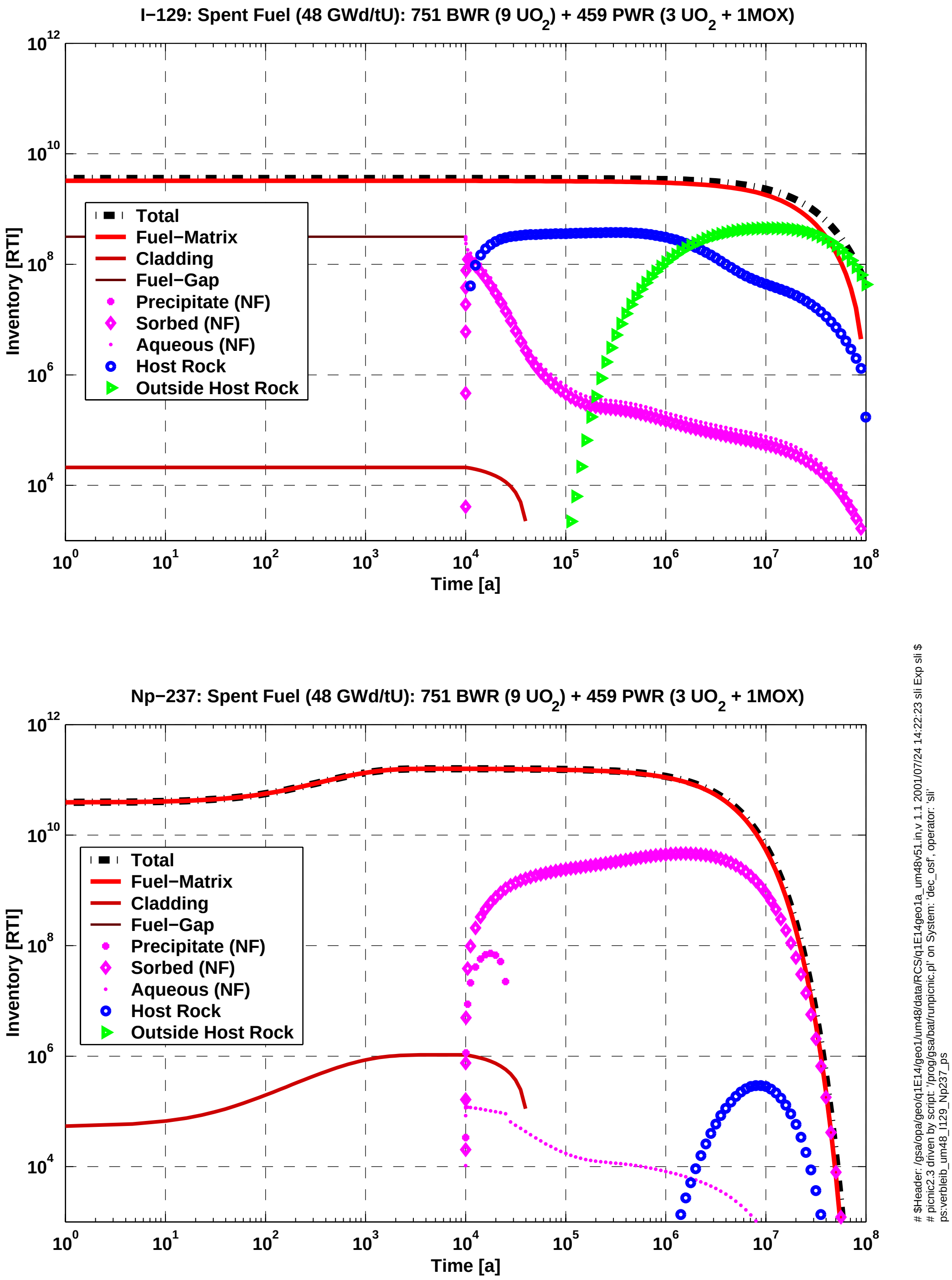


Figure 4. **The distribution of radiotoxicity (expressed as an RTI) originating from SF and its evolution, showing the different components of the near field.**



Note: Bars beneath the graph indicate the radionuclides that make the highest contribution to radiotoxicity at any particular time and in any particular part of the system

Figure 5. **The distribution of radiotoxicities (expressed as RTIs) originating from SF due to ^{129}I (upper figure) and ^{237}Np (lower figure), and their evolution.**



Note: The increase in total RTI of ^{237}Np over the period of 100 to 1000 years after emplacement is due to radioactive ingrowth.

Figure 6. **Possible deviations in the evolution of the disposal system**

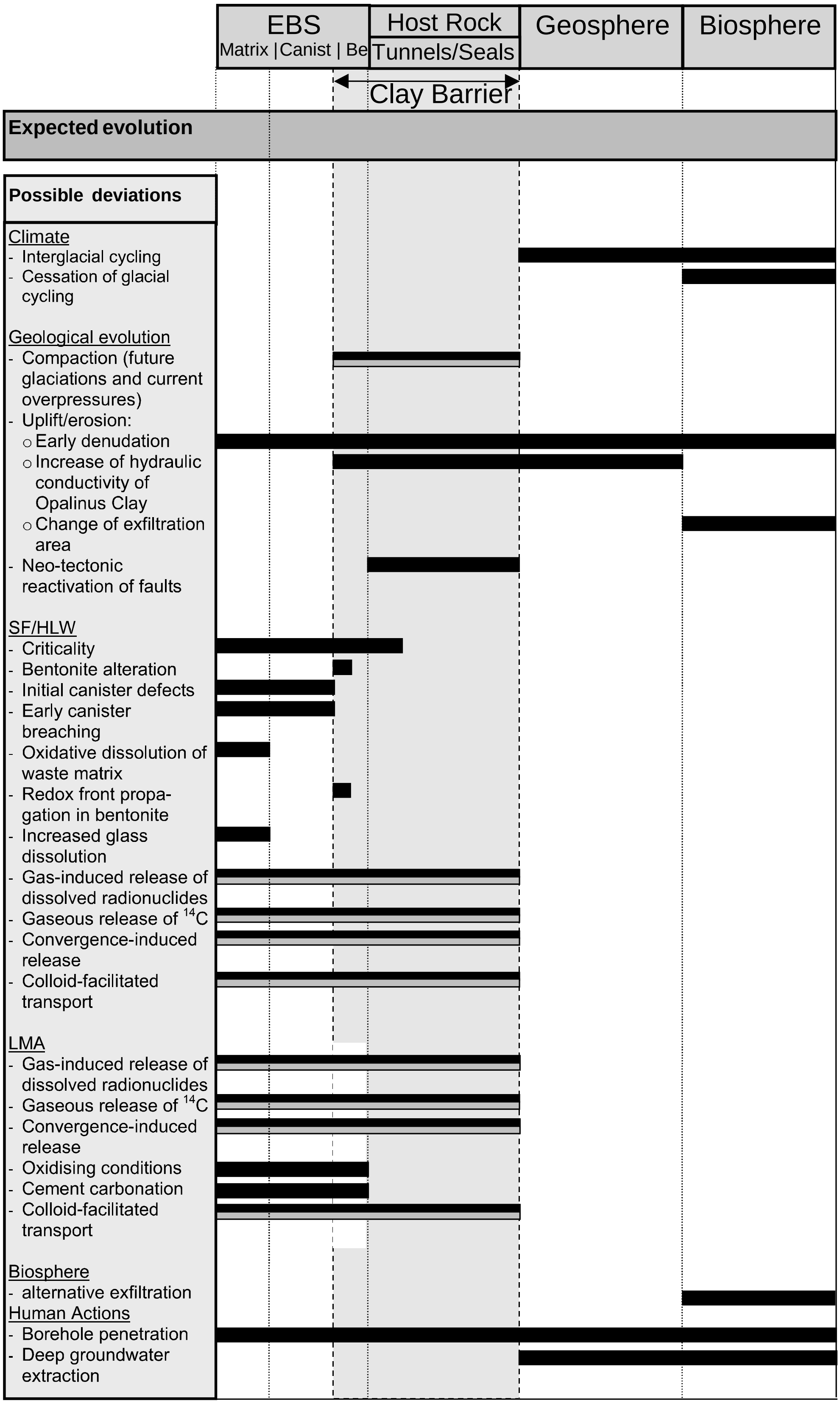
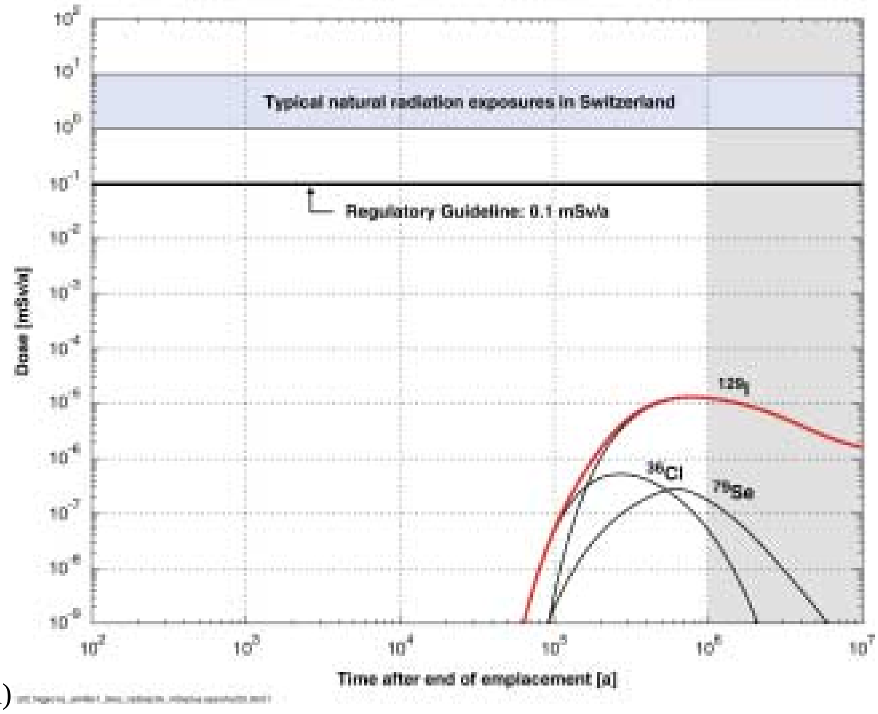


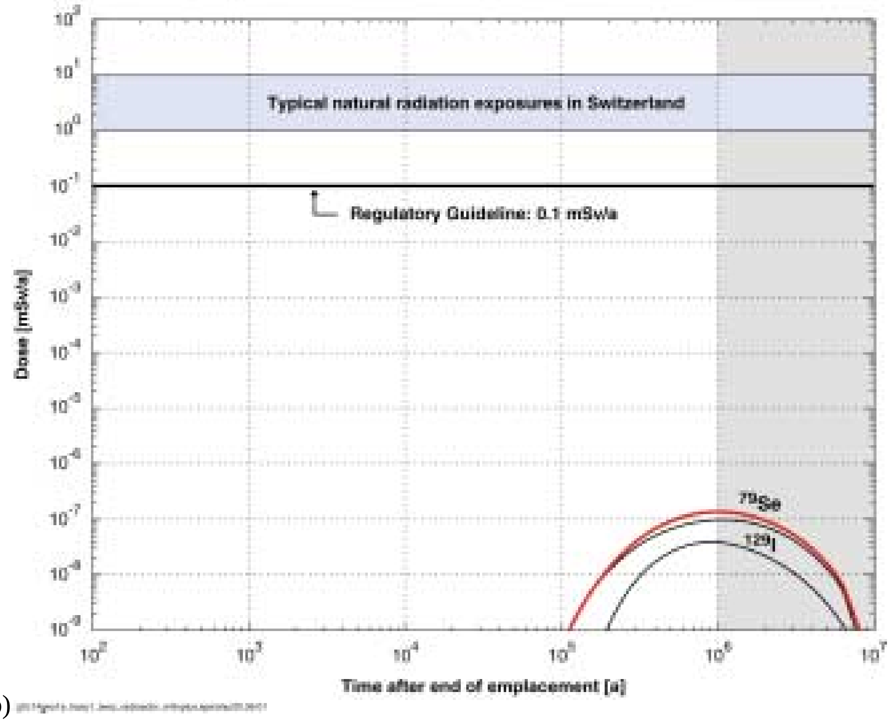
Figure 7. **Scheme illustrating the different calculation cases considered**

Scenarios addressing scenario uncertainty	**Alternative conceptualisations**	**Parameter variations**
Release of radionuclides through intact host rock (**Reference scenario**)	Dissipation of compaction-induced overpressures (Reference Conceptualisation)	**Reference Case**
		Effect of SF canister loading
		60 year NPP lifetime .
		....
	Bentonite alteration	Base Case only
	Initial canister defect	Small / large pinhole
	....	
Release of radionuclides through perturbed host rock	Network of gas microfissures	Two different values for hydraulic conductivity of host rock
	Gas-induced release of dissolved radionuclides.......	Two different steel corrosion rates (SF); Two different water flow rates (ILW)
Release of radionuclides through ramp/shaft	Dissipation of compaction-induced overpressures	Sealed/backfilled repository
		Abandoned repository
		Colloid-facilitated release
	.....	
Release of radionuclide affected by uplift/erosion	Increase of hydraulic conductivity of host rock	hydraulic conductivity of host rock
	Change of exfiltration area	Base Case only
Release of radionuclide affected by inadvertent human intrusion	Borehole penetration	Near hit; direct hit
	Deep groundwater extraction from Malm aquifer	Two different degrees of contamination

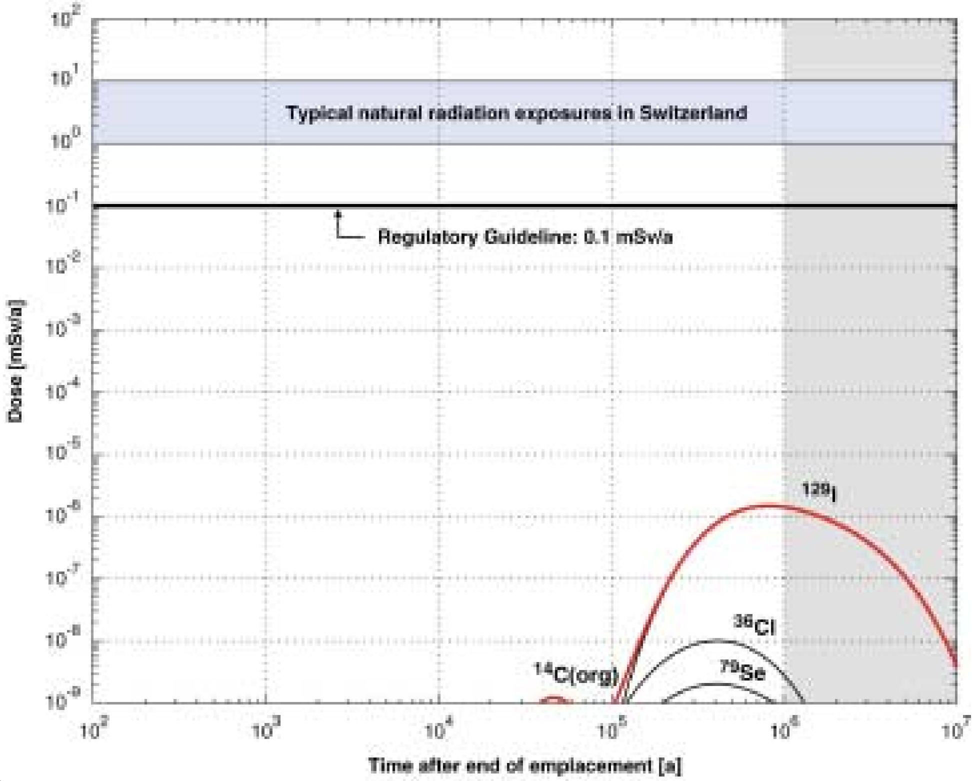
Figure 8. **Dose rates for the Reference Case (in mSv/a) as a function of time after the end of waste emplacement: a) SF, b) HLW, c) ILW (for LMA-1; the dose rates for LMA-2 are about an order of magnitude lower).**



a)

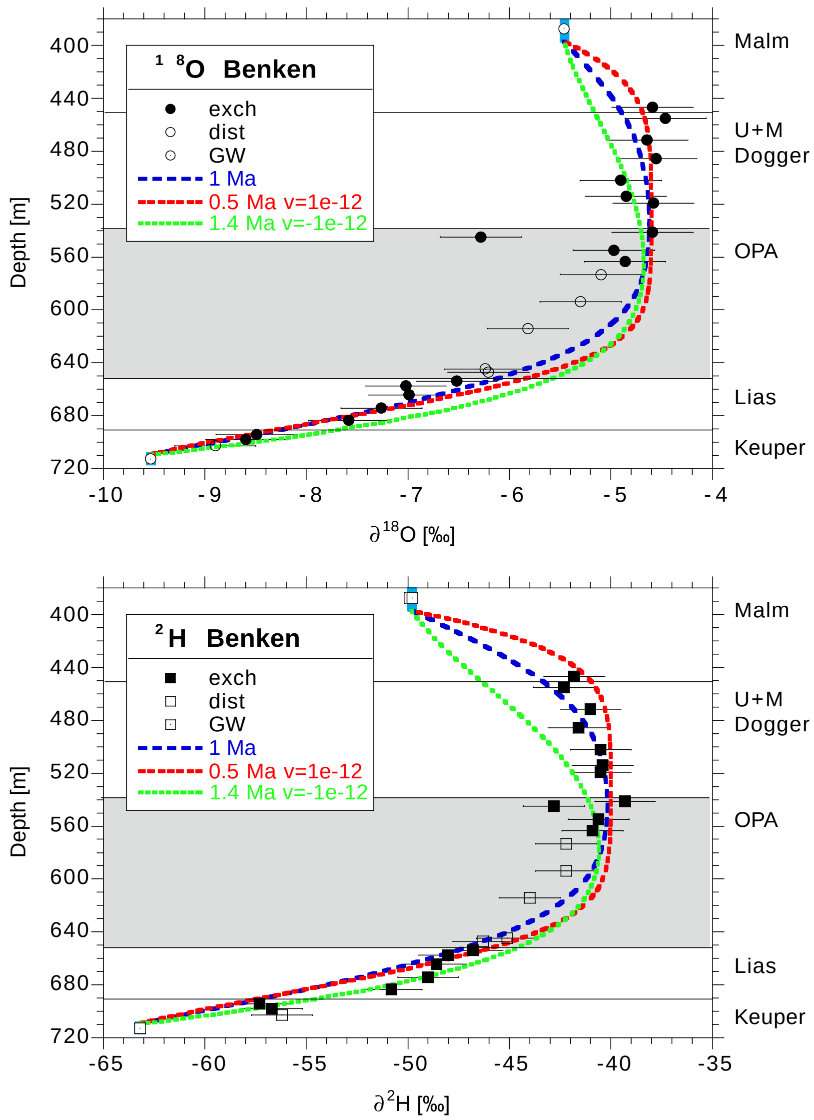


b)


Typical natural radiation exposures in Switzerland
Regulatory Guideline: 0.1 mSv/a
Dose [mSv/a]
129I
36Cl
79Se
14C(org)
Time after end of emplacement [a]

c)

Figure 9. **Isotope concentration profiles across the Opalinus Clay (OPA) and adjacent rock strata, comparing measured data obtained under different conditions (labelled "exch", "dist" and "GW") and preliminary modelling results assuming diffusion only (blue lines), diffusion and upwardly directed advection (red lines) and diffusion and downwardly directed advection (green lines). The times in the legend indicate how long the model system has been allowed to evolve from an assumed initial state of uniformly high concentrations in the Dogger, OPA and Lias and the fixed present-day (lower) concentrations in the Malm and the Keuper in order to produce the three curves. v is the assumed advection velocity in ms^{-1}.**



FIRST SAFETY ASSESSMENT
OBJECTIVES AND CONTENT OF THE 2001 REPORT

Michel de Franco
Andra, France

At the end of 2005, Andra must submit to its supervisory ministers a report on the disposal possibilities for high-level long-lived radioactive waste (HLLL waste) in deep geological formations with due account to a reversibility rationale. This report will describe the results achieved so far and provide an opinion on the feasibility of a repository that "would respect nature, environment and health, while integrating the rights of future generations".

With that goal in mind, Andra organised its activities according to a Development Plan (DP) in order to determine the nature and schedule of the various tasks to be conducted. Year 2001 marks a relevant step in the iterative process. Moreover, without any predefined cut-off step either on research matters or in the field, 2001 was selected to prepare the first compilation of scientific and technical data and to undertake the first safety assessment of the chosen designs that the Agency is currently investigating.

The purpose of this note is to describe the objectives of the 2001 report and its content.

Objectives and expected results

First and foremost, the 2001 report represents the first safety assessment of disposal designs with a view to facilitating the formalisation and testing of the safety-assessment method that the Agency intends to use for its 2005 report due to the government. The report therefore comprises a significant methodological component, although the results of this first safety assessment constitute an additional goal of the report. The 2001 report also includes an exercise in compiling and formatting the scientific information underlying the safety assessment and the approach used to study the feasibility of the repository.

The 2001 report will therefore offer an opportunity for dialogue with the Agency's various stakeholders, such as the National Review Board (*Commission Nationale d'Evaluation* – CNE), the Nuclear Safety Inspectorate (*Direction de la Sûreté des Installations Nucléaires – DSIN*), the Institute for Radiation Protection and Nuclear Safety (*Institut de Protection et de Sûreté Nucléaire – IPSN*), etc. It is essential for Andra to be in a position to show early enough the content of its safety assessment of chosen designs with respect to their feasibility, as well as the associated arguments and methods. From that standpoint, the 2001 report constitutes the Agency's proposal on the issue. The readability of such a document is crucial. Feedbacks of reviews will be a manner to improve its clarity and demonstrativeness.

The 2001 report doesn't aim to make a demonstration of the feasibility of any potential repository. Some parts of the safety assessment will only be partially developed, since the methods to be adopted are common to those described elsewhere in the document and their use does not raise any problem or specific issues. For obvious reasons, any information obtained at such an early stage may only be limited. In that sense, the report does not aim at exhaustiveness or completeness. That is particularly the case for the quantitative analyses (concentration and dose calculations) presented in this report that do not involve the entire inventory of radionuclides or toxic chemicals contained in the waste. A few elements have been selected for the calculations, either because of their potential impact or representativeness with regard to the behaviour of radionuclides or of their belonging to a chemical family. In addition, any uncertainty or discrepancy within the report, whether it concerns a simple gap, a partially covered aspect or unverified hypotheses, will be identified in a view of later processing and further study, if necessary.

Nevertheless, the 2001 report is not restricted to methodological objectives. Its conclusions will also allow to underscore lessons for safety's sake with regard to disposal designs as well as studies and investigations to be performed until 2005.

The conclusions of this first safety assessment will in particular permit to get a feedback on the design approach: the 2001 safety assessment will provide elements to support a multi-criteria analysis on the performance of those designs. The Agency is planning to select by the beginning of 2002 the relevant designs to be more investigated until 2005, through a multi-criteria analysis. The multi-criteria analysis includes, beside safety, the following criteria: (i) demonstrativeness, (ii) reversibility, and (iii) cost and (iv) flexibility with regard to the inventory.

A qualitative analysis will also be carried out on the various chosen designs, for both the operational and post-closure phases. One of its objectives is to evaluate the contribution of each option of design to the safety. The assessment of the safety criterion that was performed on the previous designs during the preliminary phase will rely up on the work mentioned in the 2001 report. Moreover, the 2001 report will provide elements for the reversibility and demonstrativeness criteria. Additional studies[1] may also introduce other elements for consideration.

Lessons learnt from the first safety assessment will bring to the fore the relevant design' elements and phenomenological processes with regard to safety and its demonstration. Such will be the particular case of the role of the quantitative calculations and sensitivity analyses to be conducted at different scales (vault, disposal module and geological medium). The calculations that are performed on each design and a restricted list of radionuclides aim at determining the exact role of the main components and at ranking the transfer pathways. The 2001 report will also provide the first bases to identify the major safety elements. The first goal of the calculations carried out in the framework of the 2001 report is not to quantify precisely the impact of a potential repository on a defined outlet and to examine exhaustively any potential impact of all the elements involved. Such an objective would require complete calculations on the entire radiological and chemical inventory, a task that will not be undertaken in 2001. Given the feedback from current experiences, only major radionuclides or those representative of typical behaviours (whether mobile or not, delayed or not, etc.) will be considered. Calculations will aim at quantifying their contribution to the impact and to derive a more global evaluation of the role of each family in that impact. For that purpose, calculations will be made for some designs and for each family of Intermediate level waste (HLW) waste, vitrified waste and spent fuels.

1 Excluded from the 2001report *stricto sensu*: further design studies, cost studies, etc.

Finally, the 2001 report will also offer an opportunity for verifying the availability of the scientific and technical informations that are needed to perform the safety analysis, for ensuring their consistency, for identifying discrepancies and underlining uncertainties. In that sense, the 2001 report will compile the available knowledge.

Structure

All information acquired during the whole process of the research project on the HLLL-waste repository is reported into technical reports. In addition, both safety analyses and calculations give rise to specific reports whose content and articulation often reflect the series of tasks scheduled and carried out at the Agency.

The 2001 report will consist mostly of a summary report describing the overall approach, the different components and the main conclusions. In addition, the report will include several supporting technical reports and notes. Although those documents were prepared in respect with the rationale adopted for the development of the HLLL-waste project, any reader could consult them separately according to the information being sought.

Content

The 2001 report contains five major parts:

- the knowledge reference systems;
- the description of the preliminary repository designs;
- the description of the phenomenological evolution of a repository;
- the safety analysis;
- an international review of safety-related approaches.

The 2001 report presents a first set of the Agency's reflections on the reversibility, especially the relevant components required for the reversibility and monitoring programme. The report also includes an executive summary.

Knowledge reference systems

Knowledge reference systems reflect the status at the end of 2001 of all acquired scientific informations together will the scientific and technical uncertainties. They include four volumes:

- The reference system on "packages" consists of the preliminary inventory model (*modèle d'inventaire préliminaire* – MIP) and of a the first description of the associated phenomenological processes (e.g source terms). The MIP presents a detailed listing of all families of the HLLL-waste packages. It also defines hypotheses for production predictions, draws up an inventory, describes the various package types and provides radiological inventories, as well as radiological and thermal characteristics in consistency with each type of waste package. The phenomenology chapter mentions clear information on the behaviour of the various packages, especially the release of radionuclides;
- The reference system on the "geology" presents the available state of art on the current technical and scientific knowledge regarding the Eastern Site. The document updates, the first version released the Agency in January 1999, especially with respect to the hydrogeological modelling;

- The reference system on “materials” presents the current knowledge on engineered materials that might be used or present in a repository (hydraulic binders, clays and metals). It focuses on information concerning the physical, chemical and containment properties of hydraulic binders and clays that are currently investigated by the Agency, as well as data on the corrosion and mechanical behaviour of carbon steels and other passivable alloys;
- The reference system on the “biosphere and the environment” describes the initial characteristics of the Eastern Site. It provides a status report on the behaviour of radionuclides and toxic chemicals in the various media as well on the transfers to the food chain; the impact on human beings, the flora and fauna. Finally, it provides a representation of the various biospheres, and the resulting conceptual and mathematical models.

Description of the concepts submitted to safety assessment

This part describes the preliminary designs selected for the three waste categories (ILW waste, vitrified waste and spent fuels), together with facility-construction, operation and closure processes. It also includes the functional analysis of the repository and its components during with the operational and post-closure phases.

Description of the repository’s phenomenological evolution

This part involves the phenomenological analysis of repository situations (analyse phénoménologique des situations de stockage – APSS). This analysis consists in describing the Agency’s understanding about the role of each relevant component of the chosen designs, by identifying the different thermal, hydraulic, mechanical and chemical (THMC) phenomena regulating the evolution of the repository throughout the different phases of its lifetime. Achievement of this goal relies on an analysis segmenting the repository’s lifetime in time and spaces frames, in order to describe as completely as possible the phenomenology and to establish a link with the models to be developed after 2001.

Safety analysis

This part presents the approach adopted for the safety analysis, the assessment methods and the end results.

It includes a qualitative safety analysis throughout the operational and reversibility phases, along with an analysis of specific risks (package drop, fire and criticality) and a qualitative safety analysis during the post-closure phase. The post closure safety analysis comprises a risk and failure assessment leading to the description of scenarios in a view of carrying out a quantitative assessment (dose and concentration calculations): normal-evolution scenario (scénario d’évolution normale – SEN) or altered-evolution scenario (scénario d’évolution altérée – SEA) such as human intrusion, sealing failure.

The modelling hypotheses, arguments for the tool selection, results of numerical simulations and their interpretation are described in this part. Calculations are made at different successive space scales (vault, disposal modules, repository and host formation, geological medium and environment).

Reversibility analysis

Andra defines a "reversible repository" as a disposal facility that is capable, to the same extent as a storage facility, of providing options at all times with regard to waste management and of remaining robust over time with regard to the basic objective of protecting human beings and the environment. This goal suggests that the operator of a repository is in a position to control the evolution of the repository and to manage it at each reversibility level. In that context, it is vital to understand the thermal, hydraulic, mechanical, chemical or radiological phenomena involved in order to determine the repository's evolution. To achieve that goal, it is necessary to benefit from an adequate system to monitor the repository and its reference models. The next step consists in defining the means of action on the management and evolution of the repository.

This part will present a first overview on:

- The relationships between reversibility and the different design factors of the repository (architecture and specifications, implementation and operational processes and phases of the repository, as well as appropriate technological means necessary to revert to a previous reversibility level);
- The feasibility and the objectives of the monitoring programme.

Review of foreign approaches

This part describes some foreign approaches in connection with safety analyses, particularly NIREX (United Kingdom) and SKB (Sweden). It also provides a summary of the approaches developed abroad for the definition of "safety scenario" and for the use of analytical methods, safety models and associated numerical calculations.

Executive summary

This document highlights the different elements of each chapter of the report and presents the main lessons and conclusions. It also establishes the relevant links with the various parts of the report. Finally, it might be read and understood independently from the latter by the various stakeholders.

Conclusion

The 2001 report will not demonstrate the safety of any specific repository design. However, it will allow for:

- the methods to be tested before the safety assessment that will be performed by 2005 ,
- the first lessons to be learnt with regard to the identification of the major safety-related design elements and phenomenological processes,
- and also for underscoring of the existing scientific and technical information as a base or a justification for the safety assessment.

Beyond its actual completion, the 2001 report must be exploited first to gather all useful lessons in order to determine which repository designs will be considered and, also, to revise Andra's Research and Development programme.

In the early months of 2002, relevant designs and their associated research programme will be selected and argued on the basis of the report and of other corollary elements (cost analysis, specific studies on concepts, etc.) and will be examined between 2002 and 2005. Furthermore, a certain amount of work will remain to be carried out in order to further the specification process of the HLLL packages.

SR'97 PEER REVIEW: FEEDBACK ON THE INTEGRATION OF COMMENTS IN THE STEP-WISE PROCESS

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1. BACKGROUND

In December 1999, SKB delivered the Safety Report SR 97 [1], treating the long term safety of a deep repository for spent nuclear fuel using site data from three field investigations in different parts of Sweden. The report was an important part of the material requested by the Swedish government prior to a decision regarding SKB's suggested site investigations.

SR 97 was reviewed by SKI and SSI [2] and, at SKIs initiative, by a team of international experts nominated by the NEA [3]. This paper gives a short account of the review comments and of how they are used to improve the KBS 3 safety case.

2. CONCLUSIONS IN PEER REVIEWS

2.1 Conclusions of the NEA Review Team

The chapter related to the conclusions of the final report by the NEA review team is reproduced below:

"The KBS-3 disposal concept has the essential elements of a sound concept for the disposal of spent nuclear fuel in a geologic repository. It provides defence-in-depth through a set of passive barriers with multiple safety functions. The concept is based on well-established science and a firm technological foundation, is well defined, and appears to be implementable.

SR'97 provides a sensible illustration of the potential safety of the KBS-3 concept that takes account of the conditions in Swedish bedrock, based on data from three sites. The documentation is generally well written and the arguments are well presented, but there is room for improvements in the completeness of arguments, traceability and transparency.

Given the current state of expertise of the SKB geoscience and engineering programmes and the favourable indications from SR 97, SKB's desire to move to a site-selection phase is well founded. This is reinforced by the observations that the performance of the geosphere barrier is site-specific and data are needed from potential sites to better develop, focus and test the SKB assessment methodology.

The review has not identified urgent issues that must be resolved prior to proceeding to the investigation of potential sites. Several observations and recommendations are made that SKB and the safety authorities may wish to consider in the future development of the Swedish safety assessment programme for spent fuel disposal:

- A high-level, periodically updated document describing SKB's safety strategy should be prepared. This would reveal the evolution of the KBS-3 concept and show how various technical studies have contributed to its development and to the understanding of the requirements for safety;
- More frequent, iterative safety assessments would facilitate the timely evaluation of the significance of new scientific and engineering information and enhance the role of safety assessment as a means to integrate the programme. More frequent assessments would also develop and ensure the continuity of staff experience and skills required to conduct such assessments;
- A number of technical issues have been identified, the resolution of which would enhance the robustness and transparency of the descriptions and arguments that support the safety case. More important examples relate to:
  - Documentation of the evidence and arguments leading to confidence in the maintenance of reducing groundwater conditions at repository depth;
  - Improved understanding of the origin and evolution of groundwater solutes;
  - Interpretation of the "flow-wetted surface" parameter, including methods to provide field data necessary to support its use, and;
  - Definition of the expectations and requirements of biosphere modelling consistent with Swedish regulatory guidance and scientific constraints.
- Better definition of SKB's strategy for scenario selection could clarify the representativeness and purpose of the different scenarios, and how they build to an integrated evaluation of safety. In future assessments, more formal scenario development or selection techniques would be preferable;
- It would be beneficial to develop an integrated, and more comprehensive, approach to uncertainty and sensitivity analysis that covers a fuller range of parameter and model uncertainties and evaluates multi-parameter sensitivities. Improved transparency is needed in the selection of parameter values defined as "realistic" or "pessimistic" in SKB's current method. Methods that permit the construction of probability distributions from limited amounts of data should be reconsidered;
- Discussion is required between SKB, SKI and SSI on the interpretation of the Swedish regulatory requirements related to risk and probability, the authorities' expectations, and practical methods that might be employed to calculate desired endpoints while preserving statistical veracity. Discussion is also required with SSI regarding their expectations for assessing impacts to the natural environment and how requirements might be met;

- In future safety assessments, consideration should be given to incorporating more realistic, as opposed to conservative, descriptions of the performance of the facility. The adaptation and completeness of the present scenarios to the conditions of specific sites should also be considered;
- Incorporation of more comprehensive sensitivity and uncertainty analyses into the assessment methodology could help to guide site investigations, and specifically to identify which site-specific data are most important to safety and potentially to be obtained during the site characterisation programme."

2.2 Conclusions of Swedish regulatory review

SKI and SSI presented their review of SR 97 in November 2000 in the form of a main report and a summary report. The following is a quotation of the conclusions in the summary [2]:

- "No circumstances have emerged in SR 97 to indicate that geological disposal in accordance with SKB's method should have any crucial deficiencies in relation to the requirements made by the authorities on safety and radiation protection;
- SR 97 contains the constituents required to provide a comprehensive picture of safety and radiation protection;
- SKB's methodology for safety assessment has been improved in several important areas, for example as regards documentation of processes and properties that can affect repository performance, and development of calculation models for the safety assessment;
- The methodology in SR 97 has some deficiencies, for example when it comes to specifying which future events the safety assessment shall describe. SR 97 has not dealt enough with unfavourable conditions that can affect the future safety of a final repository;
- SKB says that the results of SR 97 have been used in the work of formulating requirements and preferences regarding the rock at a final repository. In the opinion of the authorities, it is not clear from SR 97 how this has been done. The coupling between site assessment and site investigations should be improved;
- A safety assessment of a final repository for spent nuclear fuel will always be burdened with uncertainties and deficiencies in the knowledge base. It is then up to experts to make the best possible judgements. SKB should develop better procedures for expert judgements.

In summary, the authorities conclude that parts of the methodology in SR 97 need to be further refined and defined in preparation for upcoming stages in the site selection process. SKB's development of methods for safety assessment is an ongoing effort that should continue throughout all stages of the construction of a repository.

After the review of SR 97 and the previous review of SKB's RD&D Programme, the authorities find that the KBS-3 method is a good foundation for SKB's future site investigations and the continued development of the engineered barriers.

The authorities intend to return with additional viewpoints regarding what reporting is needed at the different junctures in SKB's final disposal programme in conjunction with future reviews of SKB's RD&D programmes.

The summary report also states: “But a detailed body of data from site investigations and more extensive practical experience from fabrication and testing of the engineered barriers are required before a more exhaustive assessment can be made of the KBS-3 method. It is moreover necessary that SKB augment and refine its methods for safety assessment, taking into account the authorities’ review of SR 97.”

3. HOW ARE THE CONCLUSIONS USED TO IMPROVE THE SAFETY CASE?

It is urgent for SKB that the safety assessment be subjected to both national and international reviews. A safety assessment of the scope of SR 97 has not been done since the KBS-3 report was presented in 1984. Since then both methodology and the body of scientific data have developed considerably and it is important that SKB’s assessment be reviewed by leading experts in this field.

The overall purpose of SR 97 was to present a Safety Case which would allow a decision to commence site investigations to be taken. SKB concludes that no obstacles to proceeding with site investigations have emerged in the reviews of SR 97. On the contrary, both the NEA Review Team and the Swedish regulatory authorities consider data from site investigations to be of urgent importance for being able to evaluate the KBS-3 method in greater detail.

Both review teams identified a number of issues where there is room for improvement, concerning e g process understanding and PA methodology. Many of the issues were also identified by SKB, either directly in the SR 97 report or otherwise. Below follows a brief account of how this information is used in the continued development of the KBS 3 safety case.

3.1 Process understanding

One of the corner stones of the SR 97 reporting was the so-called Process Report [4], where relevant information on all identified long-term processes was given. In SKB’s recently published RD&D programme 2001 [5], all identified processes are discussed and a systematic account of the SR 97 review comments is given for each process. Together with SKB’s own evaluation of remaining uncertainties, a research programme for the next three-year period is formulated. Alternatively, a process might be regarded as sufficiently well understood from the point of view of long-term safety and the corresponding field is monitored.

3.2 PA Methodology

Also SKB’s program for the development of PA methodology is accounted for in the RD&D programme 2001. Also here, a systematic account of review comments and other sources is given and the main items for development in the next three-year period are:

- Format for the system description and plans for a modernised Process Report;
- Scenario development;
- Method for probabilistic calculations;
- Role of natural analogues in future assessments;
- Possibilities for feedback from the safety assessment to the site investigations and the repository design;

- Programme for future safety assessments, including interim assessments in preparation for the comprehensive assessments that will be based on data from the site investigations.

It is SKB's intention to report methodology developments in the end of 2002, and possibly have the report reviewed internationally.

3.3 Other areas influenced by the reviews

The reporting style, structure and level of detail in the SR 97 reports has been on the whole favourably received which is an important feedback for upcoming reporting. However, for some issues brought up in the reviews, much of the discussions could have been avoided had the reporting been clearer or more detailed. This is e.g. the case for the evidence given for the maintenance of reducing groundwater conditions at repository depth, which was found insufficiently, reported by the NEA review team. Also this is important feedback in order to improve future reporting.

Another effect of the comments from NEA team was the acceleration of the discussions between SKB and SSI concerning the interpretation of SSI's recently issued regulations on the protection of human health and the environment in connection with the final management of spent nuclear fuel and nuclear waste (SSI FS 1998:1).

Finally, as mentioned above, SKB has not presented a comprehensive safety assessment of the KBS 3 method for many years. This Safety Case as a whole has therefore not been discussed internationally in the form of critical reviews for a long time. The process of presenting and defending the Safety Case to critically evaluating peers has been an excellent training experience for the SKB PA team on both the national and international arenas.

References

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The Total System Performance Assessment/Site Recommendation International Peer Review

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The US Department of Energy (DOE) requested the International Atomic Energy Agency (IAEA), jointly with the OECD's Nuclear Energy Agency, to provide, on the basis of available international standards and guidance, an independent evaluation of the total system performance assessment methodology developed by the DOE Yucca Mountain Site Characterization Office (YMSCO).

In response, an International Review Team (IRT) was organized by a Joint Secretariat formed by Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA). IAEA participated in the context of that Agency's statutory functions to perform services useful in research on, and development or practical application of, atomic energy for peaceful purposes, and to establish international standards of safety and provide for their application. The NEA participated under its mandate for improving and harmonizing the technical basis for dealing with nuclear waste related issues among its member countries.

The primary subject of review was the document entitled the Total System Performance Assessment - Site Recommendation (TSPA-SR). Supporting documents were made available (e.g., Process Model Reports and Analysis Model Reports), as was documentation of work performed during the period of the review and its documentation. The primary focus of the review, however, was the TSPA-SR document, however.

Two meetings were held in Las Vegas (June, August 2001), and three exchanges of questions and responses by email took place between meetings. At the end of the August meeting preliminary results were orally presented. An Executive Summary was due to DOE end October (delivered on time), and a final report is due to DOE in January 2002 (expected to be delivered as scheduled).

The presentation at the IGSC meeting was based solely on the recollections of the presenter who was in the audience where the IRT gave an overview of very preliminary impressions that the DOE's:

- TSPA-SR methodology conforms to international practice;
- TSPA-SR is appropriate for addressing the regulatory compliance requirements that are the basis for the site recommendation decision;
- TSPA-SR and process models need more work, however, if it is to provide regulatory "reasonable assurance" of safety, or is to become part of a comprehensive safety case with considerations that go beyond regulatory compliance.

At the IGSC meeting some impressions were given of the technical detail to be expected in the final report. It was made clear that these were strictly unofficial accounts of what may become IRT observations:

- Good choices were made for waste package and drip shield materials, but more experimental work is needed to provide firmer basis for modeling;
- The cladding model needs a firmer basis;
- The assumed movement of radionuclides out of waste packages through continuous films of water is incredible, not just conservative;
- Unsaturated flow and transport modeling is good, but active fracture model needs validation;
- Saturated zone flow and transport modeling needs additional site specific work and a new regional model;
- Uncertainties need an overall strategy for evaluation and reduction;
- Some large uncertainty ranges conservative at process level, but may be non-conservative at system level (dose dilution, needs evaluation);
- More could be done to evaluate human intrusion;
- Several FEPs (features, events and processes) were suggested that need evaluation;
- Documentation is not yet sufficiently transparent.

The presenter's personal impressions of what was reported by the IRT at the end of August suggested this was a technically critical review, but balanced. The experience level of reviewers was apparent early in process, since meaningful areas of weakness quickly identified, and there were instances of critical observations based on known problems faced in other nations' evaluations of long-term safety.

An important issue for the IRT was the ability to compare safety evaluations of different nations' potential repositories. The U.S. regulatory performance measure does not allow such comparison (time constraint combined with locational specificity is unique), and investigating the possible use of alternative performance measures was suggested for greater comparability. Also, several times it was observed that this may have been a good example of a system-level safety evaluation, but it was not a good example of a safety case. A safety case requires showing understanding, and that may mean doing calculations simply because they provide insight. An example of such a calculation that was mentioned was calculating beyond the regulatory compliance period and boundary, and showing the potential fate of radionuclides in the Yucca Mountain setting, which is a hydrologically closed basin, beyond 10,000 years and 20 km.

After the final IRT report is received by the DOE, it will be responded to.

ICRP POLICY

FOR RADIOACTIVE WASTE DISPOSAL

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Introduction

The 1990 recommendations of the International Commission on Radiological Protection (ICRP) provided a coherent system of radiological protection, which considered all kinds of situations [1]. During the following decade, ICRP elaborated precise recommendations dealing with specific situations and domains, which required clarification and precise advice. Radioactive waste management was recognised as one priority, especially because of the increasing concern of the public about potential health effects, which might affect future generations. In 1985, ICRP issued a publication on the disposal of solid radioactive waste, which was an application of the 1977 recommendations [2].

In 1997, ICRP issued *Radiological Protection policy for the disposal of radioactive* waste, which explains, clarifies and extends the 1990 recommendations [3]. This relatively short report deals with all types of radioactive waste, liquids as well as solids. It explains the application of the three basic principles of radiological protection to waste disposal, i.e. justification of the practice, optimisation of protection, dose and risk limitation. Since its creation in the fifties, the quantity collective dose has often been misunderstood and misused; this publication discusses the use of collective dose assessed over long distance and times. In addition, the report discusses the implications of potential exposures and the distinction between practice and intervention.

In 1998, ICRP produced *radiological protection recommendations applied to the disposal of long-lived solid radioactive waste*, which applies to new disposal facilities [4]. It considers the specific problem of human intrusion into a waste disposal facility and discusses values for generic reference levels, since the use of a constrained optimisation is not suitable in this case.

Radiological protection of the population, when applied to radioactive waste enters the general frame of “prolonged exposures”. It should be recognised that ICRP Publication 60 does not provide clear answers to the questions raised by long-term situations; thorny issues include criteria for differentiating between practice and intervention as well as between limits and reference levels, the specific role of limits and constraints, etc. In 1999, ICRP explained its general philosophy on these matters in *Protection of the public in situations of prolonged radiation exposure* [5].

General philosophy

In its Publication 77, ICRP recalls that the main protection issue in waste disposal is public exposure. For radiation protection purposes, ICRP considers the differences between the two strategies "Dilute/Disperse" and "Concentrate/Retain"; an early direct discharge of waste to the environment results in doses to critical groups while waste retention eliminates or reduces short-term public exposure. This explains why the second strategy appears currently as the more protective, even if identification of critical groups meets a lot of difficulties. In this context, ICRP recommends that *the disposal of radioactive waste should not be automatically regarded as less suitable than retention. Both strategies are necessary and a suitable balance between the two should be sought.*

Although the principle of justification applies doubtless to waste disposal operations, these activities should not be regarded as freestanding practices with their own justification. Waste management and disposal operations are an integral part of the practice, which generates the waste. If there is a change in national waste policy, then justification of the whole practice has to be re-evaluated.

Current national protection policies make confusion between optimisation and the best available technology (provided that it does not entail excessive cost). In addition, optimisation is often taken as "best environmental point of view, regardless of cost". ICRP states clearly that this view *falls short of achieving the optimisation of protection* and that its policy is *more subtle and judgmental,* than is implied by differential cost-benefit analysis (reduction in collective dose vs incremental cost of protection). As in activities other than waste disposal, constrained optimisation is a key issue for the protection of the public. A value for the dose constraint of no more than 0.3 mSv in a year is applicable to waste disposal (by definition, a constraint is source-related and should be used for prospective purposes). If the constraint is exceeded, the situation should not be regarded as an infringement of regulation, but the whole process of optimisation should be reassessed.

In the context of waste disposal, the demonstration of compliance with the dose limits shows intrinsic difficulties, especially because of the multiplicity of sources to which members of the public are exposed. Therefore, restrictions should be developed for application to monitoring results, based on a dose to critical groups for which the mean individual dose is near 1 mSv in a year. The general conclusion is that *direct use of limits for the public becomes obviated* and that *limits should progressively fall out of use.*

Collective doses are currently used for the rough assessment of the general detriment to an exposed population. Because of the problems related to its use for large populations exposed to very small doses, ICRP clarifies its use when assessing the exposure (and detriment) to a given population from waste disposal. The first issue is that a collective dose due to small individual doses should not be ignored on the sole ground that these doses are small. It would be appropriate to identify the component of collective dose which is related to very small doses and, for decision making, to give different weights to the various components with regards to mean individual doses. The second issue is related to the period of time during which a group of population is exposed to waste disposal; uncertainties on individual doses, population size and dose-detriment relationship increase as time increases. ICRP considers that *decisions must be made on a case-by-case basis* and *forecasts of collective dose over periods longer than several thousand years and forecasts of detriment over periods longer than several hundred years should be examined critically*. Consequently, ICRP recommends a desegregation of collective doses, by ranges of individual dose; each block should extend over no more than one or two orders of magnitude. The same rule applies to time periods (in years). A similar desegregation applies to other parameters, such as the nature and severity of the health effects when using collective dose for the assessment of health effects (do not aggregate general detriment and cancers in specific organs, lethal cancers and cancers with a high cure rate, etc.).

In practices and intervention, it is almost certain that exposures will occur and their magnitude is predictable, indeed with some degree of uncertainty. Sometimes, there is a potential for exposure, but not certainty that it will occur. These exposures are called potential exposures, although it is often possible to apply some degree of control to both their probability and their magnitude. In the context of waste disposal, a distinction should be made between the two optional strategies "Dilute/Disperse" and "Concentrate/Retain". In the first option decision making is based on the evaluation of the exposure of a critical group, which should be correctly protected. In the second option, exposures are potential and difficult to assess; some form of intervention will obtain their reduction. The choice between the two strategies will be based on the comparison of exposures, taking into account both their magnitude and their probability of occurrence.

The last question raised by ICRP is protection of future generations. ICRP recognises that there are ethical questions in judging the importance of harm imposed to future generations from decisions taken in the present. ICRP recommends at least three relevant quantities on which judgement can be based: the total detriment on a given population over many generations, the total detriment on a defined generation and the detriment during a defined period (a year, a life-time) on individuals of hypothetical critical groups. In conclusion, ICRP suggests that *the annual individual dose (normal exposure) or risk (potential exposure) will provide an adequate input to a comparison of the limiting detriment to future generations with that which is currently applied to the present generation.*

Disposal of long-lived solid radioactive waste

ICRP Publication 81 pays attention to the specific problems raised by the disposal of long-lived solid radioactive waste. The main issue is the protection of the public in a remote future from waste produced by the current generation and the application of the optimisation principle to probable scenarios, with special consideration to human intrusion.

ICRP acknowledges the basic principle that individuals and populations in the future should be afforded at least the same level of protection from actions taken today as is the current generation. Although the health detriment cannot be forecast with accuracy for periods beyond around several hundreds of years, ICRP considers that estimates of doses (or risks) can be made for comparison with appropriate criteria; this process should be considered as a test to give an indication whether the repository is acceptable, but should never be regarded as an assessment of future health detriment. ICRP continues to recommend that exposures should be evaluated on the basis of the mean annual dose to critical groups, which should be seen as hypothetical. Provided that habits and characteristics of critical groups are chosen with reasonably conservative assumptions, it is possible to calculate the annual dose averaged over the lifetime of the individuals, on the credible assumption that radioactive contamination of the biosphere is likely to be relatively constant over this period. In general, different scenarios with different probabilities of occurrence will be plausible, each one being associated with a specific critical group; for decision-making, the different possibilities of exposure and their probabilities should be examined separately.

Exposure of individuals may be due either to natural processes or to human intrusion. For "natural processes", ICRP considers that the key criterion is the individual source related constraint; the recommended upper value is 0.3 mSv in a year, which corresponds to a risk constraint of about 10^{-5} per year. Compliance with the dose (or risk) constraint can be demonstrated through two different ways: either an aggregated approach combining doses and probabilities (i.e. using a risk constraint) or a desegregated one considering separately dose and probability (i.e. using a dose constraint plus the probability that the dose will be incurred). Whatever the approach, aggregated or desegregated, the use of a constraint is relevant in the case of natural processes. On the contrary, for human intrusion, which cannot be totally ruled out, protection can be achieved only by efforts to reduce the possibility of such events. The significance of human intrusion, which has by-passed all the barriers considered during the optimisation process and results in inescapable consequences, may be assessed using a risk-based approach considering both the probability of intrusion and the possible consequences. Since constraint applies during the process of optimisation of protection and scientific bases for reliable predictions are missing, the use of constraints is not relevant for human intrusion. Therefore intervention should be decided on the basis of generic reference levels. Such criteria are established on the basis of the *existing annual dose*, defined as *the sum of all significant components of annual doses incurred by a typical individual in an exposed group of people, from all relevant sources and via all pathways, of a human habitat subject to a prolonged exposure situation* [5]. These generic reference levels can be applied in a large range of situations where exposures are prolonged over long periods of time. They are developed in a sister-publication, which is summarised below.

Protection of the public in situation of prolonged exposures

ICRP Publication 60 did not pay special attention to prolonged exposures, for various reasons: natural sources are generally excluded from the scope of regulations, some prolonged exposures are controllable (such as many exposures to natural sources and exposures to radioactive residues), some others are not *controllable* (exposure to natural radionuclides present in the body) or unnameable to control (exposure to cosmic radiation). The merit of Publication 82 on prolonged exposures is to provide a general frame for different situations, coherent with the philosophy developed in previous ICRP publications. In addition, it provides generic quantitative recommendations for intervention.

There are many situations where individuals of the public are or may be exposed during long periods of their life or even during their whole lifespan. These situations include natural radiation sources that may give rise to relatively high doses, restoration and rehabilitation of sites where human activities involving radioactive substances have been carried out, the return to normality following an accident that has released radioactive material to *the* environment and global marketing of commodities for public consumption that contain radioactive substances.

The justification of a practice, which delivers prolonged exposure, requires that all relevant long-term components be considered prior to the adoption of the practice, while the optimisation of protection requires the selection of the best radiological protection option for any source. In addition to the criteria previously recommended by ICRP, such as dose and risk constraints, dose limits, exemption levels, intervention levels, action levels, etc., ICRP felt that, because of the specificity of prolonged exposures, some others were necessary. Consequently, ICRP recommends the use of a generic reference level for intervention, expressed in terms of existing annual dose. Two other subsidiary quantities were needed in this context: *the additional dose from a practice*, which is added to the existing annual dose and may be amenable to restrictions during the operation of the practice, and *the annual dose averted by intervention*, which corresponds to the reduction of the annual dose by the intervention. The latter was already defined for accidental situations [6]. One advantage of these quantities is that they are directly comparable with current values of the background; this is not the case for limits and constrains, which are implicitly expressed in terms of additional annual dose.

The generic reference levels for interventions recommended by ICRP (including those necessary after human intrusion in a waste repository) are consequently expressed in terms of existing annual dose; ICRP considers that intervention is not likely to be justifiable below 10 mSv, while it will almost always be justified above 100 mSv. Below 10 mSv, protective actions to reduce a dominant component of the existing annual dose are still optional and might be justifiable. Between 10 and 100 mSv, intervention may possibly be necessary and should be justified on a case-by-case basis. If the situation results into doses that are around or above the threshold for deterministic effects, intervention is required.

ICRP warns against some misuses of these generic reference levels: (i) they should be used with great caution; (ii) if some controllable components of the existing annual dose are dominant, specific protective actions to reduce these components may be implemented; for example, a relatively high level of natural radiation should not prevent a reduction of artificial components that are controllable; (iii) generic reference levels should not be applied to the various components of the existing dose and therefore authorise abstaining intervention.

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EXTRACT OF THE [NEA/RWM(2001)4] REPORT RELATED TO THE BOOKLET ON CONFIDENCE/SAFETY CASE [1]

Background

When the NEA "Confidence Document" was published, the RWMC suggested that a booklet should be developed that would be directed at technical experts outside the waste management field. While the original members of the working group were in agreement, it was later decided to give the development of the "brochure" a lower priority because of 1) a lack of Secretariat resources during the re-organisation of the RWMC structure, and (2) new initiatives, such as IPAG-3, that would provide materials that could contribute to the brochure.

In the past year the Integration Group for the Safety Case (IGSC) has become operational, and it has become important to this group to develop a common view of what a Safety Case is. A short document has been envisaged to describe a common basis understanding. This could be used not only in the work of the IGSC, but it would also help explain to others the purpose and work of the IGSC.

Because the confidence brochure would deal with the same generic topic – the Safety Case -, it was deemed reasonable to combine *the two initiatives into one dealing with the long-term Safety Case and the underlying confidence aspects.*

Some Observations

The link between the Safety Case and decision making is important

For a Safety Case to be successful, it must fully satisfy the purpose and objectives that were initially set out for the work. The purpose for a Safety Case is to contribute to decision-making regarding the development and licensing of a radioactive waste repository. It is acknowledged that the decision making process takes place in discrete steps and, at each time, the Safety Case must contribute to the decision to be made.

1 The report was presented at the RWM meeting on March 2001

There cannot be one detailed recipe that is valid for all

The scope and detail of the Safety Case will vary based on the decision at hand, and cultural differences between countries on the degree of detail required for decision-making. The more straightforward and direct safety cases can be equally as valid as the complex and detailed safety cases, as both can be used for decision-making for repository development. Because of this, one must look at the Safety Case as being somewhat conceptual, as it will not be possible to develop a recipe or formula for creating a Safety Case that will be valid for all. On the other hand, it must be possible to present the general guidelines.

Start with the general ingredients identified in the confidence document

The confidence document definition implies that, at a higher level, four main ingredients are required to make a safety case:

- collection of arguments, which includes a safety assessment, that supports long-term safety;
- statement of why stakeholders and decision-makers should have confidence in the arguments and safety assessment showing long-term safety (i.e.; why the arguments and Safety Case provide a sufficient basis for making the decision at hand);
- acknowledgement of unresolved issues that are potentially important to safety;
- guidance or discussion of "way forward" to resolving those issues.

Start with some general issues about confidence, credibility, and uncertainty

Some of the general issues that must be dealt with are as follows:

- Confidence in the message and in the messenger: How is this taken into account?
- Lack of complete predictability: why is it still reasonable to move forward?
- Level of integration: is all collected information properly used and does it lead to a consistent picture of the system?
- Lack of completeness in the types and quality of the information that could be mustered: how was it addressed and what are the potential ramifications of uncertainties?
- Lack of complete agreement amongst technical experts: how was this disagreement taken into account in the analyses?

Combine above ingredients with the identified issues

To the extent possible, avoid using insider jargon and terminology. Describe in common language and sentences the elements, approaches and arguments that can contribute to addressing those issues in the context of the step-wise decision-making process in developing a safety case. In any event, make sure that technical terms are explained, e.g., in a glossary in the document.

Start with available materials

From the confidence document, the June 2000 IGSC topical session, the IPAG series of reports, international peer reviews, plus the cumulative knowledge the IGSC, a lot of material is available on ideas and approaches for assembling the "collection of arguments" needed to support long-term safety, and for illustrating "why one should have confidence" in the safety assessment. On the other hand, it must be acknowledged from the start that it may prove difficult and time-consuming to distil this material into a compact booklet.

The final goal

The early drafts of the brochure should be discussed and used in the work of the RWMC and, especially, the IGSC. Eventually, the brochure should be a document accessible to non-specialists. In addition to describing the Safety Case and its confidence bases, it should show that it is feasible to create a Safety Case upon which a decision can be made. In this regard, the brochure will reinforce the 1991 Collective Opinion on "Can Long-Term Safety be Evaluated?" The brochure will thus describe the issues connected to the Safety Case and the approaches available for satisfying the four elements of a safety case. It would not imply that all techniques and approaches need to be used in every safety case. Rather, it would provide a sense of the problems that exist, the range of techniques and approaches that can be used to formulate the Safety Case and develop and communicate confidence.

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