Radioactive Waste Management
Gestion des déchets radioactifs

OECD OCDE

Establishing and Communicating Confidence in the Safety of Deep Geologic Disposal

Établir et faire partager la confiance dans la sûreté des dépôts en grande profondeur

Approaches and Arguments

Approches et arguments

AEN
NEA

NUCLEAR • ENERGY • AGENCY

Radioactive Waste Management
Gestion des déchets radioactifs

Establishing and Communicating Confidence in the Safety of Deep Geologic Disposal

Approaches and Arguments

Établir et faire partager la confiance dans la sûreté des dépôts en grande profondeur

Approches et arguments

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

AGENCE POUR L'ÉNERGIE NUCLÉAIRE
ORGANISATION DE COOPÉRATION ET DE DÉVELOPPEMENT ÉCONOMIQUES

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 27 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

ORGANISATION DE COOPÉRATION ET DE DÉVELOPPEMENT ÉCONOMIQUES

En vertu de l'article 1er de la Convention signée le 14 décembre 1960, à Paris, et entrée en vigueur le 30 septembre 1961, l'Organisation de coopération et de développement économiques (OCDE) a pour objectif de promouvoir des politiques visant :

- à réaliser la plus forte expansion de l'économie et de l'emploi et une progression du niveau de vie dans les pays Membres, tout en maintenant la stabilité financière, et à contribuer ainsi au développement de l'économie mondiale ;
- à contribuer à une saine expansion économique dans les pays Membres, ainsi que les pays non membres, en voie de développement économique ;
- à contribuer à l'expansion du commerce mondial sur une base multilatérale et non discriminatoire conformément aux obligations internationales.

Les pays Membres originaires de l'OCDE sont : l'Allemagne, l'Autriche, la Belgique, le Canada, le Danemark, l'Espagne, les États-Unis, la France, la Grèce, l'Irlande, l'Islande, l'Italie, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni, la Suède, la Suisse et la Turquie. Les pays suivants sont ultérieurement devenus Membres par adhésion aux dates indiquées ci-après : le Japon (28 avril 1964), la Finlande (28 janvier 1969), l'Australie (7 juin 1971), la Nouvelle-Zélande (29 mai 1973), le Mexique (18 mai 1994), la République tchèque (21 décembre 1995), la Hongrie (7 mai 1996), la Pologne (22 novembre 1996), la Corée (12 décembre 1996) et la République slovaque (14 décembre 2000). La Commission des Communautés européennes participe aux travaux de l'OCDE (article 13 de la Convention de l'OCDE).

L'AGENCE DE L'OCDE POUR L'ÉNERGIE NUCLÉAIRE

L'Agence de l'OCDE pour l'énergie nucléaire (AEN) a été créée le 1er février 1958 sous le nom d'Agence européenne pour l'énergie nucléaire de l'OECE. Elle a pris sa dénomination actuelle le 20 avril 1972, lorsque le Japon est devenu son premier pays Membre de plein exercice non européen. L'Agence compte actuellement 27 pays Membres de l'OCDE : l'Allemagne, l'Australie, l'Autriche, la Belgique, le Canada, le Danemark, l'Espagne, les États-Unis, la Finlande, la France, la Grèce, la Hongrie, l'Irlande, l'Islande, l'Italie, le Japon, le Luxembourg, le Mexique, la Norvège, les Pays-Bas, le Portugal, la République de Corée, la République tchèque, le Royaume-Uni, la Suède, la Suisse et la Turquie. La Commission des Communautés européennes participe également à ses travaux.

La mission de l'AEN est :

- d'aider ses pays Membres à maintenir et à approfondir, par l'intermédiaire de la coopération internationale, les bases scientifiques, technologiques et juridiques indispensables à une utilisation sûre, respectueuse de l'environnement et économique de l'énergie nucléaire à des fins pacifiques ; et
- de fournir des évaluations faisant autorité et de dégager des convergences de vues sur des questions importantes qui serviront aux gouvernements à définir leur politique nucléaire, et contribueront aux analyses plus générales des politiques réalisées par l'OCDE concernant des aspects tels que l'énergie et le développement durable.

Les domaines de compétence de l'AEN comprennent la sûreté nucléaire et le régime des autorisations, la gestion des déchets radioactifs, la radioprotection, les sciences nucléaires, les aspects économiques et technologiques du cycle du combustible, le droit et la responsabilité nucléaires et l'information du public. La Banque de données de l'AEN procure aux pays participants des services scientifiques concernant les données nucléaires et les programmes de calcul.

Pour ces activités, ainsi que pour d'autres travaux connexes, l'AEN collabore étroitement avec l'Agence internationale de l'énergie atomique à Vienne, avec laquelle un Accord de coopération est en vigueur, ainsi qu'avec d'autres organisations internationales opérant dans le domaine de l'énergie nucléaire.

AVANT PROPOS

Le Groupe consultatif de l'AEN sur l'évaluation des performances des systèmes d'évacuation des déchets radioactifs (PAAG) a établi en 1994 un Groupe de travail sur les évaluations intégrées des performances des dépôts géologiques profonds (IPAG). La mission générale de l'IPAG est d'offrir une plate-forme cadre privilégié pour mener des discussions sur l'évaluation de la sûreté et des performances, et de procéder à un examen de l'état d'avancement général des dossiers de sûreté et des études d'évaluation intégrée des performances (EIP) menées à l'appui de ces derniers. Ces travaux ont été menés en plusieurs phases, la composition et les tâches du Groupe pouvant changer d'une phase à une autre.

Au cours de la Phase 1 (IPAG-1), l'objectif a été d'examiner les études les plus récentes d'évaluation des performances. Il s'agissait d'avoir un ensemble concret d'éléments d'appréciation susceptibles de refléter l'état actuel de l'évaluation des performances et de signaler ce qui peut et devrait être fait lors d'études futures. Les travaux ont été menés principalement de juin 1995 à avril 1996 et sont décrits dans un rapport de l'AEN/OCDE de 1997 [NEA, 1997].

Au cours de la Phase 2 (IPAG-2), l'objectif visé était de faire le point sur l'expérience des examens par des pairs sur les évaluations intégrées des performances et plus particulièrement des revues qui ont servi d'appui technique à une évaluation d'ordre réglementaire, du point de vue tant des autorités de sûreté que des exploitants. Les travaux menés principalement de mai 1997 à octobre 1998, sont décrits dans un rapport de l'AEN/OCDE de 2000 [NEA, 2000-a].

Au cours de la Phase 3 (IPAG-3), le Groupe a évalué les méthodes et arguments qui ont été utilisés pour instaurer et communiquer la confiance dans la sûreté. L'IPAG-3 avait pour objectifs d'évaluer l'état de l'art pour gagner, exposer et démontrer la confiance dans la sûreté à long terme, et de formuler des recommandations pour les orientations et initiatives futures en vue d'améliorer la confiance. Ces travaux, qui ont été menés principalement de juin 1999 à novembre 2000, fait l'objet de ce présent rapport.

FOREWORD

The NEA Performance Assessment Advisory Group (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 Phase 1, IPAG-1, the goal was to examine recently completed IPA studies as a practical body of evidence that would indicate the current status of PA and could shed light on what can and should be done in future studies. The work was carried out mainly between June 1995 and April 1996, and was documented in an OECD/NEA 1997 report [NEA, 1997].

In Phase 2, IPAG-2, 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 work was carried out mainly between May 1997 and October 1998, and was documented in an OECD/NEA 2000 report [NEA, 2000-a].

In Phase 3, IPAG-3, 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. IPAG-3 was carried out mainly between June 1999 and November 2000, and is documented in this report.

REMERCIEMENTS

La Division de la gestion des déchets radioactifs de l'AEN remercie chaleureusement les organisations suivantes qui ont apporté à ce projet un soutien financier et en nature : ANDRA, BfS, CCSN, ENRESA, GRS, HSK, JNC, CEDRA, UK Nirex Ltd., ONDRAF, OPG, Posiva Oy, SÚRAO, SKB, SKI, UKEA et USDOE.

Elle exprime en particulier sa gratitude à Ontario Power Generation (OPG) qui a aimablement accueilli la réunion de travail de l'IPAG-3 à Toronto, Canada du 3 au 4 mai 2000. Les participants à cette réunion de travail sont aussi sincèrement remerciés de leur contribution technique et de leurs précieuses analyses et observations.

Les principaux auteurs qui ont contribué à ce rapport sont :

- Doug Metcalfe (CCSN, Président de l'IPAG-3) ;
- Claudio Pescatore (AEN/OCDE) et Alan Hedin (SKB) pour le chapitre 2 ;
- Lucy Bailey (UK Nirex Ltd.) pour le chapitre 3 ;
- Johan Anderson (Streamflow, Inc.) pour l'annexe A ;
- Abe van Luik (USDOE) pour l'annexe B ;
- Sylvie Voinis (AEN/OCDE) pour sa collaboration à l'établissement de la version finale du rapport.

Les membres du RWMC, du Groupe d'intégration pour le dossier de sûreté (IGSC) et du Forum sur la confiance des parties prenantes (FSC) sont également remerciés de leurs commentaires relatifs à des versions antérieures du présent document.

ACKNOWLEDGEMENTS

The NEA Division of Radioactive Waste Management acknowledges the following organisations that provided financial and in-kind support for this project: ANDRA, BfS, CNSC, ENRESA, GRS, HSK, JNC, NAGRA, UK Nirex Ltd, ONDRAF/NIRAS, OPG, Posiva Oy, RAWRA, SKB, SKI, UKEA and USDOE.

Ontario Power Generation (OPG) is thanked for graciously hosting the IPAG-3 workshop in Toronto, Canada on May 3-5, 2000. The participants at the workshop are also sincerely thanked for their technical contribution and for their valuable reviews and comments.

Lead authors for this report were:

- Doug Metcalfe (CNSC, IPAG-3 Chairman);
- Claudio Pescatore (OECD/NEA) and Alan Hedin (SKB) for Chapter 2;
- Lucy Bailey (UK Nirex Ltd) for Chapter 3;
- Johan Andersson (Streamflow,Inc) for Appendix A;
- Abe van Luik (USDOE) for Appendix B;
- Sylvie Voinis (OECD/NEA) for her collaboration in the finalisation of the report.

RWMC, IGSC, IPAG-3 and FSC members are also thanked for their review comments on early versions of this document.

TABLE DES MATIÈRES

Avant-propos 4

Exposé de synthèse 147

1. Introduction 151

2. Préparer la voie à l’argumentation en vue de gagner la confiance 159

2.1 La confiance et le processus d’aménagement des dépôts géologiques destinés à des déchets radioactifs à vie longue 159

2.2 Asseoir la confiance technique dans la sûreté à long terme 162

3. Développer et documenter les arguments pour gagner la confiance 165

3.1 Confiance dans le système d’évacuation 166

3.2 Confiance dans les données et dans la connaissance du système de stockage 169

3.3 Confiance dans la méthode d’évaluation 171

3.4 Confiance dans les modèles 172

3.5 Confiance dans les analyses du dossier de sûreté et de l’EIP 174

3.6 Confiance par le biais du retour sur la conception et la caractérisation du site 177

4. Considérations finales 179

4.1 L’expérience de l’IPAG-3 179

4.2 Comparaison des résultats de l’IPAG-3 à ceux de l’IPAG-1 et de l’IPAG-2, de même qu’avec le document de l’AEN sur la confiance 179

5. Références 181

Acronymes 183

Annexes A – D : Version anglaise seulement (voir pages 43-141)

TABLE OF CONTENTS

Foreword 5

Executive summary 11

1. **Introduction** 15

2. **Setting the stage for making confidence arguments** 21

    2.1 Confidence and the process for developing geologic repositories for long-lived radioactive waste 21

    2.2 Building technical confidence in long-term safety 23

3. **Developing and documenting confidence arguments** 27

    3.1 Confidence in the disposal system 28

    3.2 Confidence in the data and knowledge of the disposal system 31

    3.3 Confidence in the assessment approach 32

    3.4 Confidence in the IPA models 33

    3.5 Confidence in the safety case and IPA analyses 35

    3.6 Confidence via feedback to design and site characterisation 38

4. **Final considerations** 39

    4.1 The IPAG-3 experience 39

    4.2 Comparison of the findings of IPAG-3 with those from IPAG-1 and IPAG-2, and with the NEA Confidence Document 39

5. **References** 41

***Appendix A**:* The compilation of the questionnaire answers 43

***Appendix B**:* Making oral presentations about a safety case 111

***Appendix C**:* The IPAG-3 initiative and its questionnaire on approaches and arguments used to establish confidence in long-term safety and the overall results of IPAs 123

Appendix D: List of members and additional participants to Toronto meeting 135

Acronyms 143

EXECUTIVE SUMMARY

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

---

[1] The PAAG and SEDE were replaced by the NEA Integration Group for the Safety case (IGSC) in 2000.

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
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.

1. INTRODUCTION

Implementing and regulatory organisations in many of the OECD Member countries are involved in the investigation and resolution of issues associated with the long-term safety of underground repositories for radioactive waste. In every national radioactive waste management programme, the safety case is the focus of both the implementer's and regulator's activities. Safety must be demonstrated to the satisfaction of the implementing organisations, the regulatory bodies, the wider scientific and technical community, political decision-makers and the general public. In particular, convincing arguments are required that instil in these groups confidence in the safety of the proposed repository, taking into account the uncertainties that inevitably exist in forecasting the behaviour of complex natural and engineered systems for long times into the future.

The safety case is the integration of arguments at a given stage of repository development in support of the long-term safety of the repository [NEA, 1999]. The safety case should provide a statement of confidence in the overall assessment of long-term safety, and argue the adequacy of the present science, engineering, and modelling work for the stage of repository development or function being addressed. It also should include an acknowledgement and discussion of uncertainties and unresolved issues, and provide a road map to the work being planned to resolve those issues.

The basis for a safety case lies in science and engineering, and this is reflected in the detailed and rigorous modelling conducted to evaluate the long-term performance of the disposal system. The key technical document that supports the safety case is commonly referred to as an Integrated Performance Assessment (IPA). The IPA presents and discusses the modelling and analyses conducted, the calculated measures and indicators of long-term safety and performance, and the uncertainties in those safety and performance measures. The safety case then places the results of the IPA into a context with other factors and considerations relevant to the decision at hand, such as the relevant regulations, qualitative arguments based on insights from nature, information from engineering and materials experience and the overall decision-making process.

To date, several safety cases and IPAs have been completed and reviewed, both nationally and internationally. These documents and the associated reviews can be evaluated to draw lessons for preparing, presenting, and reviewing safety cases and IPAs. The commonalties indicate areas of consensus, and the differences may serve to highlight areas for further reflection and improvement. In 1994 the NEA Radioactive Waste Management Committee (RWMC) and its Performance Assessment Advisory Group (PAAG) set up the Working Group on Integrated Performance Assessments of Deep Repositories (IPAG) to provide a forum for informed discussion on issues related to the preparation, presentation and review of safety cases and IPAs. The findings from the first two phases of IPAG (IPAG-1 and IPAG-2) have been published previously [NEA 1997 and 2000-a], and this report presents the findings from the third phase of IPAG (IPAG-3).

When the IPAG was set up and during Phases 1 and 2, the terms "safety case" and "IPA" were not clearly distinguished. The term "IPA" was used to describe the overall safety case as well as the underlying technical document that presented the assessments of long-term repository performance. As such, the next paragraph that summarizes IPAG-1 and IPAG-2 refers to "IPAs" only. However, in this report, following the NEA confidence document [NEA 1999], the distinction is made between a "safety case" and an "IPA" as discussed above.

In IPAG-1, IPAs from ten national organizations were examined to assess the current status of performance assessment and to shed light on what can and should be done in future IPAs. In IPAG-2, the goal was to examine the experience from regulatory reviews of IPAs, from both the implementer's and regulator's point of view. In particular, IPAG-2 focused on the approaches used to review IPAs, the ways IPA reviews are presented and interpreted, the experiences of both regulators and implementers in the regulatory review process, and opinions on future directions and changes needed for regulatory decision making. Seventeen national organizations participated in Phase 2, where each had either carried out or reviewed a recent IPA study.

Several implementing and regulatory organisations are now approaching a period in which they may be called on to make and explain programmatic and licensing decisions. The actions of both implementing and regulatory organisations are likely to be subject to detailed public and political scrutiny. For the third phase of IPAG, the RWMC and PAAG decided that it would be timely to evaluate 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 recomendations on future directions and initiatives for improving confidence. IPAG-3 was carried out between June 1999 and November 2000 under the Chairmanship of D. Metcalfe (CNSC, Canada) and proceeded as follows:

- Participation was elicited from implementers and regulators who had experience in preparing or reviewing safety cases and IPAs;
- Information was collected through the use of a questionnaire distributed to all waste management organisations represented within PAAG and the Site Evaluation and Design of Experiments Co-ordinating Group (SEDE). The questionnaire had been previously tested amongst a core group of organisations. The final questionnaire requested information on the approaches and arguments that have been used to establish and communicate confidence in safety and IPAs, and opinions on future directions and changes needed for decision making;
- Twenty organisations from twelve countries, representing both implementing organisations and regulatory bodies, responded to the questionnaire as summarized in Table 1.[2] This table also identifies the stage of the development of the programme for each organisation and the factual basis from which they contributed to the IPAG-3 questionnaire.

---

[2] Table 1 is also presented in Appendix A. The references for the documents cited in Table 1 are provided at the end of Appendix A.

Table 1. **Organisations contributing to IPAG-3**
Stage of development and goal of the safety case or IPA

Organisation	**Stage of development**	**Reference materials and/or goal of assessment**
ANDRA, France	Operation authorisation applications for URLs in 1999 (one clay site at Bure and one granitic site to be determined).	Basis for selection of initial design options and of preliminary concepts (Hoorelbecke *et al*, 1998); safety approach (Voinis *et al*, 1999); scenarios (Pierlot *et al*, 1997); design description (Ben Slimane *et al*, 1999); design choice (Ben Slimane *et al*, 1999).
AECB, Canada **(replaced by the CNSC in June 2000)**	Application for a construction licence for a near-surface disposal vault at Chalk River Laboratories for short lived (500 yrs) solid wastes.	The goal of the safety case (AECL, 1996) was to obtain a construction licence. AECB response identified issues that need to be addressed before a construction licence can be issued. (Metcalfe, 1999).
BNFL, UK	A Post-Closure safety case (PCSC) is being prepared for the Drigg near surface, low-level waste disposal facility in Cumbria, UK. A PCSC is required in September 2002 to support authorisation for continued disposal operations.	In preparation for the PCSC, BNFL has published a "Status Report on the Development of the 2002 Drigg PCSC" (BNFL, 2000). It provides a detailed description of BNFL's intended approach for the 2002 radiological safety assessment. BNFL (2000).
BfS, Germany	Planned KONRAD repository located in an abandoned iron ore mine.	Support for license application of the KONRAD repository project. BfS (1990).
ENRESA, Spain	Concept development. IPA for a repository in a generic granite formation	Optimise and compare conceptual facility design, to provide input to the site selection programme and to guide R&D work. Enresa (2000).
GRS-B, Germany	The Morsleben repository is an existing facility, but further operation is limited to actions for final closure	Develop strategies for safe final closure of the repository, and to demonstrate safety by a long-term analysis. Storck *et al.* (2000).
GRS-K, Germany	Planned KONRAD repository intended for the disposal of radioactive waste with negligible heat generation.	Experts of the licensing authority prepared an expert opinion concerning the safety assessments, by examination of the license documents (here the IPA) of the applicant and preparing their own IPA. NMU (1997).

Organisation	Stage of development	Reference materials and/or goal of assessment
HSK, Switzerland	Regional studies for a HLW/ILW repository. No candidate sites, but field data exist.	See Nagra. A formal review by the regulatory authority will be needed when selecting a host rock. Review of Nagra (1994).
JNC, Japan	Generic R&D and feasibility assessment	Demonstrate technical reliability and suitability of techniques and experience to construct a repository. Basis for selection of sites and formulation of regulations. JNC (2000).
Nagra, Switzerland	See HSK. The Kristallin-I IPA marked the end of the regional phase for the crystalline option.	Re-evaluate the host rock. Improve understanding. Identify key characteristics and ranges of parameters in order to guide site selection. To develop and test the safety assessment methodology. Nagra (1994).
UK Nirex Ltd	Developing a generic (non site-specific) disposal concept.	Outline an approach to assessing post-closure performance by presenting a general description of the important factors determining repository performance, illustrated by application to six generic environments. Bailey and Littleboy (2000).
ONDRAF/ NIRAS, Belgium	State of the art on feasibility and safety of deep disposal of high level long-lived waste every ten years.	Obtain the decision to continue the programme to step to a final phase of R&D and to start around 2010 the preparation of a preliminary safety report (PSAR). SAFIR 2 (to be published in 2001), de Preter *et al*, (1999).
OPG, Canada	The concept for disposal of Canada’s nuclear fuel waste needs to be accepted before site selection will be undertaken.	Support the Environmental Impact Statement (EIS). To help assess the concept for used fuel disposal at a hypothetical site, using information from the surface and from boreholes. The IPAs forming the basis for the OPG answers are Goodwin *et al*. (1994) and Goodwin *et al*. (1996). The associated overall EIS is AECL (1994a,b).
RAWRA, Czech Republic	Preliminary stage of repository development	Show repository function and assess the sensitivity of the system with respect to input data. (RAWRA, 1999).

Organisation	Stage of development	Reference materials and/or goal of assessment
Posiva, Finland	Decision in Principle on the need of a planned spent nuclear fuel disposal facility. Selection of one site for further development.	Support Posiva's Environmental Impact Statement and the application for the Decision in Principle for a disposal facility for spent nuclear fuel. Vieno and Nordman (1999), review in Ruokola ed (2000).
SKB, Sweden	Transition from feasibility studies to site investigations (boreholes) in at least two municipalities.	Support for the transition to site investigation phase. Demonstrate feasibility of the KBS-3 concept in Sweden. Demonstrating IPA capability. SKB (1999).
SKI, Sweden	In 1988 SKB obtained a restricted operational license for the SFR repository for operational waste	The purpose of the IPA reviewed was to obtain a license for depositing the operational waste with the highest radionuclide content in a large silo that had already been constructed. Review of SKB (1987) in SKI (1988) and of SKB (1991) in SKI (1992).
UKEA, UK	Guidance on Requirements for Authorisation	No assessment for deep disposal is being review. Answered based on UKEA (1997) as well as Duerden *et al*. (1996), Yearsley and Sumerling (1998) and Sumerling (1999).
USDOE, USA	Yucca Mountain is the selected site for investigations. Next step will be to make a Site Recommendation.	The TSPA[3]-VA (DOE, 1998) addresses the rationale for repository development at Yucca Mountain, and the likelihood that the programme can meet its disposal safety objectives. No regulatory bearing. Additional documents used in preparing answers are DOE (1999), OCRWM (2000).
USNRC, USA	US NRC is preparing for review of license application in 2002	To fine tune the NRC primary review tool. Use sensitivity analyses to identify important safety aspects of the system indicating were attention should be focused during the review. NRC (1999).

- The questionnaire answers were analysed to compile the various approaches and arguments that have been used to build confidence in the long-term safety of deep geologic disposal, and evaluate the state of the art for obtaining, presenting and demonstrating confidence in safety. The answers to the questionnaire were rationalised

---

[3] TSPA means Total System Performance Assessment.

into a document hereafter referred to as "the compilation", which is provided in Appendix A of this report.

- The commonalties and differences of view were identified and discussed at a plenary meeting of IPAG-3 in Toronto, Canada in May 2000. At the meeting key issues were identified and discussed and a skeleton structure of the present document was produced. Individual IPAG-3 members prepared text for each identified area, and the texts were assembled into a draft report in October 2000. The draft was then distributed to members of the newly formed Integration Group for the safety case (IGSC)[4] for their comments.
- A topical session was held at the second IGSC meeting in November 2000 on approaches and arguments for building confidence. The results of discussions at the topical session were used to further clarify and refine the main observations of the study.

This report is based on the compilation of the questionnaire answers and the discussions at IPAG and IGSC meetings, and focuses on the practical experiences of IPAG and IGSC members in developing, communicating and reviewing approaches and arguments that attempt to build and establish confidence in long-term safety and IPAs. As noted above, several authors prepared the report, and thus the reader may notice variations in writing style from chapter to chapter in the report. This document also reflects comments received from members of the RWMC, IGSC, IPAG-3 and FSC committees, on earlier draft versions of this report. The main text describes the findings of IPAG-3, organised as follows:

- setting the stage for making confidence arguments (Chapter 2); and,
- developing and documenting confidence arguments (Chapter 3);

and presents some final considerations including comments on:

- the IPAG-3 experience (Section 4.1);
- a comparison of the findings of IPAG-3 with those from IPAG-1:
- IPAG-2 and the NEA Confidence Document (Section 4.2).

This is supported by the following appendices:

- Appendix A: the compilation of the questionnaire answers;
- Appendix B: making oral presentations on the safety case;
- Appendix C: the IPAG-3 questionnaire; and,
- Appendix D: the list of the participants in IPAG-3.

Appendix B presents the findings of a subgroup of IPAG-3 participants that met at the May 2000 Toronto IPAG meeting and discussed experiences and issues related to making oral presentations about a safety case.

---

[4] This new group subsumes activities under the previous groups PAAG and SEDE.

2. SETTING THE STAGE FOR MAKING CONFIDENCE ARGUMENTS

2.1 Confidence and the process for developing geologic repositories for long-lived radioactive waste

Geologic disposal

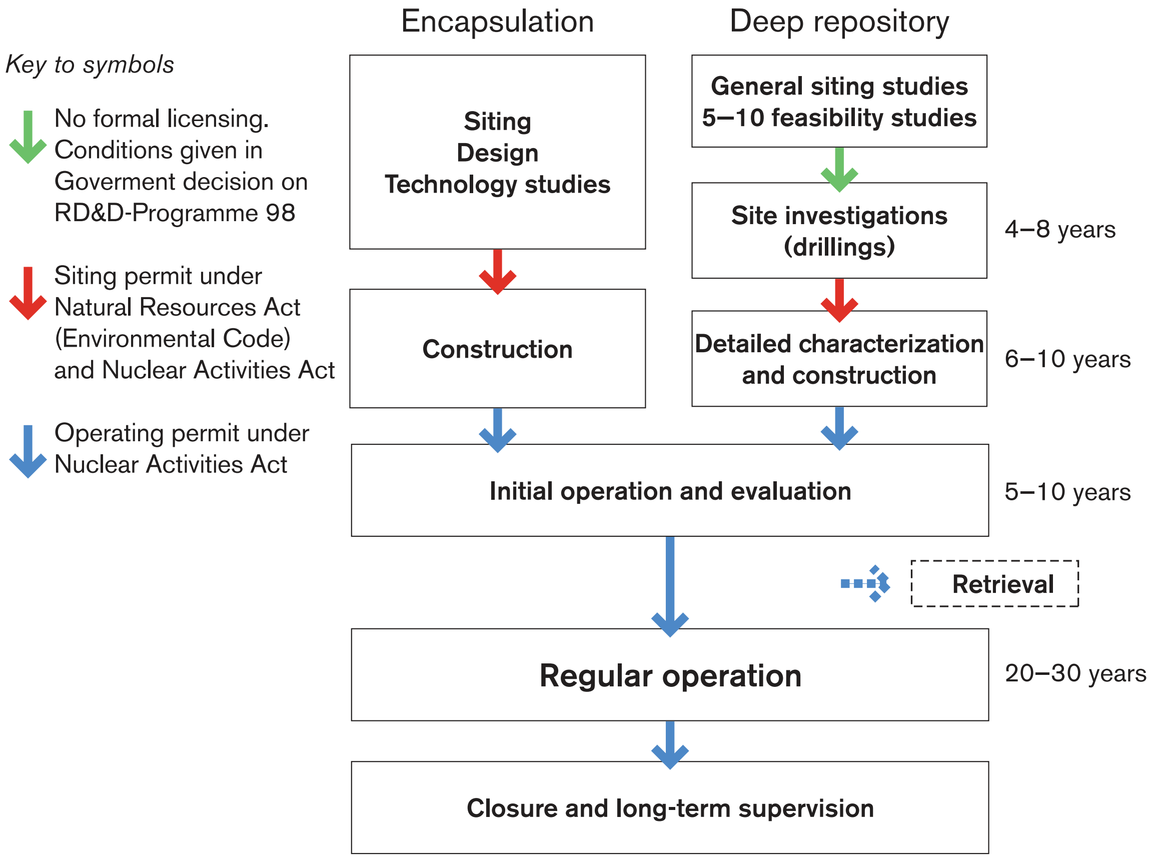
The concept of geologic disposal for long-lived radioactive waste involves deep underground repositories that provide security (for example, resistance to malicious or accidental disturbance), and containment (retention of the waste materials so that appreciable quantities of radioactivity are not released to the surface environment). The concept has been developed over many years based on a comprehensive and robust evaluation of the technical issues and ethical considerations. Potential host geologic formations are chosen for their long-term stability, their ability to accommodate the waste disposal facility, and also their ability to prevent or significantly attenuate any eventual release of radioactivity. This natural safety barrier is complemented and augmented by an engineered system designed to provide physical and chemical containment of the waste. Long-term safety and the protection of humans and the environment are thus provided in a manner that places no burden of care on future generations. Most NEA Member countries have set up radioactive waste management programmes that ultimately aim to emplace long-lived radioactive waste in a deep geologic disposal facility.

Step-wise implementation

The development of a deep geologic repository is characterised by several stages and, overall, requires several decades for completion. Figure 1 below illustrates how such a step-wise process for spent-fuel repository development is being implemented in Sweden.

The long duration of this process reflects the novelty and complexity of the tasks of elaborating a repository concept, evaluating its technological feasibility and long-term safety, and developing and testing the technology for constructing, operating and closing the repository. It also reflects 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 by one or more of the parties (e.g. the implementer, regulator or the local or state government) whether to move forward, and whether the requirements for the next development stage need to be adjusted. Therefore, the repository development process is designed to provide society with a number of opportunities to intervene and contribute to the decision-making process.

Figure 1. **The step-wise process for spent fuel repository development in Sweden**



Safety case as a basis for decisions

Generally, a safety case is one of the key bases for making decisions regarding the development of geologic repositories. A safety case may be broadly defined as a structured presentation of the evidence, analyses, and lines of reasoning related to the safety of a proposed or actual facility. This includes, but is not limited to, a description of the facility and the principles (e.g., long-term isolation) on which safety is based, as well as the strategy adopted to realise the intended principles (e.g., a research programme describing how unresolved issues will be addressed). 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.

It is important for the safety case to communicate, for each development stage, the basis for the current level of confidence in the decision to move forward, and clearly indicate the strategy for resolving the outstanding issues. Further, for a decision that relies heavily on confidence in safety, the degree of confidence in the safety case must correspond to the confidence needed for the decision. If other factors are also influential in making the decision (e.g. timing, public acceptance, budget constraints), their influence should be acknowledged.

Why is confidence of critical importance?

For decisions that are based, in part or in whole, on safety cases, consideration needs to be given to both the actual findings of the safety case and the confidence that one can place in the findings and conclusions of the safety case. This is the situation for informed decisions in any field.

The issue of long-term safety of radioactive waste repositories involves particular challenges regarding confidence due to the long time frames involved. The future evolution of the repository system may be affected, for instance, by uncertain external factors like future climates and future human activities. Given that definitive answers are not generally obtainable when complex systems are concerned, how can it be reasonably assured that all phenomena relevant to the evolution of a system have been identified and duly accounted for in the safety case? Also, in contrast to most other facilities, a repository cannot be tested or observed on the time scale over which it is intended to function. Rather, its long-term performance must be extrapolated from the results of laboratory tests, calculations, computer analyses and geologic evidence. The safety case must be firmly established before the repository is closed and even before a significant quantity of waste is emplaced, because even if monitoring and intervention may be possible, long-term safety must not rely on this.

Finally, repository designs will vary from country to country to accommodate the specific types and amounts of waste to be disposed and the characteristics of the specific host-rock being considered. Sufficient confidence that radiological and non-radiological consequences are not underestimated must be argued on the intrinsic quality of the chosen site and system design, and on the quality of the analyses of the system performance.

Confidence in the message and in the messenger

Decisions that are the responsibility of technical specialists and managers within an implementing organisation, and the regulatory bodies that oversee their activities, will require technical arguments that give confidence in the feasibility and long-term safety of the proposed concepts. Other decisions may be the responsibility of political decision makers and the general public (e.g. in local referendums). These non-technical stakeholders also require confidence in the technical aspects of repository development, but this confidence may be based on less technical, more qualitative arguments. The confidence of these groups in the technical aspects of repository development is likely to be closely related to the credibility of the implementing and regulatory organisations. This, in turn, is more likely to be achieved if support for the technical arguments of these organisations can be gained in the wider scientific community.

2.2 Building technical confidence in long-term safety

Strategic aspects

In order to favour the taking of decisions, trust is essential. Trust can be characterized as consisting of two main components: technical competence and an “affective component” which is a combination of the following social elements: openness, reliability, integrity, credibility, fairness, and caring [NEA, 2000-b]. Both components are necessary bases for trust. A perceived failure in any of the elements of the “affective component” undermines the latter component in its entirety and, with it, trusts itself. The technical competence component of trust implies that confidence is needed in, among other things, the safety case and its supporting IPA that form the technical basis for the decision to be made. The safety case will be widely reviewed by internal and external peers, and checked against the needs of varied audiences. As such, the safety case should present information clearly to a wide audience. The safety case needs to describe:

- the context in which the report was prepared;
- the safety concept, including the main features and processes upon which safety rests, and basis for confidence in their reliability;
- the principles and assumptions that were adopted, the methods that were followed, and the data and information that were used to evaluate long-term safety and develop confidence in the appropriateness of the overall safety assessment strategy;
- the results of the Integrated Performance Assessment (IPA);
- the provisions within the Research, Development, and Demonstration Programme to further demonstrate and support the safety concept; and,
- the strategies, both at the safety assessment level and at the level of the entire programme, to deal with the remaining uncertainties that are important to long-term safety.

What is enough?

Invariably, some will suggest that the information provided in a safety case or the confidence in its findings are not sufficient to permit the decision at hand to be made. To help put the safety case and its level of development in the context of the stage of repository development and the decision that needs to be made, ***IPAG-3 participants suggest the following four issues to be explicitly addressed in a safety case*****:**

- The inherent limitations in modelling the future evolution of the repository: why is it still reasonable to move forward?
- The level of integration: is all collected information properly used and does it lead to a consistent picture of the system? Alternatively, what are the potential impacts of the unresolved inconsistencies on safety?
- The completeness and quality of the various types of information and data that are available for making the safety case: what are the uncertainties and their potential impacts on Safety?
- Any disagreements amongst technical experts: how were these disagreements taken into account in the analyses?

The four points illustrate another central issue: What level of confidence should be required for a particular decision? Certain aspects of the evolution of a repository are important to safety, whereas others may have only a limited influence. This should be made clear in a safety case, to allow for a productive discussion on whether the level of confidence achieved is sufficient for decision making at each step of implementation.

The role of the step-wise decision-making process in developing confidence

The step-wise approach taken by nuclear waste management programmes offers the possibility to address both technical and non-technical issues in a manner that could be acceptable to a wide range of stakeholders. The step-wise approach to decision making offers the following benefits:

- The remaining issues and the approaches and prospects for their resolution are tabled at each stage;

- The decisions can be reviewed and revised or reversed;
- The confidence in the developers and reviewers of safety cases and the repository development and decision-making processes can be gradually developed and confirmed;
- The advantage of subdividing the process into a series of steps and thereby giving society the opportunity to form an opinion in the course of the development.

The understanding that the final safety case is made incrementally within the step-wise decision-making process for repository development is of critical importance for building confidence. The safety case needs thus to be structured, technically argued, and supported with a clear link to the step-wise decision-making process, including the decision at hand and the decisions that will be required for future steps.

3. DEVELOPING AND DOCUMENTING CONFIDENCE ARGUMENTS

The NEA Confidence Document [NEA, 1999] proposes the following description for a "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*."

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 safety case is prepared to support a decision in the repository development process, and as such confidence arguments are required to show that a sufficient base of information exists to make the decision at hand, and that it is appropriate to take the course of action recommended by the implementer. A variety of confidence arguments should be used to help build and communicate confidence to both technical reviewers and other stakeholders.

The IPAG-3 questionnaire contained a number of questions that were intended to examine the types of approaches and arguments that were used in the safety cases studied (Table 1) to build and communicate confidence. Appendix A contains a detailed analysis of these approaches and arguments, and the overall findings from that analysis are presented in this Chapter. A wide range of confidence arguments was identified in the safety cases studied. Some of the arguments were based on innovative strategies for confidence building, and there was disagreement regarding the utility and appropriateness of some these approaches. It was decided, however, to summarize all of the confidence arguments identified in IPAG-3 in this Chapter. In this way, the IPAG-3 report represents the "tool box" of approaches and arguments that have been used to build and communicate confidence in existing s and their supporting IPAs. A given safety case does not need to include all of the types of confidence arguments presented in this report. Some the confidence arguments presented may not be appropriate for some disposal systems, and other arguments may be based on confidence building strategies that require further development.

The key confidence arguments identified in IPAG-3 are categorized and summarized in Table 2. This categorization system is used below to elaborate on the findings of IPAG-3 regarding the confidence-building approaches and arguments used in existing safety cases and IPAs.

Table 2. **Key Confidence Arguments**

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
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
Confidence via feedback to design and site characterisation	• Support for any disposal concept design changes • Overall quality and safety of the disposal system

3.1 Confidence in the disposal system

Arguments are required to illustrate, demonstrate and build confidence in the intrinsic safety of the disposal system. A disposal system for radioactive waste should be designed, sited and constructed in such a manner that intrinsically favours safety and provides confidence that the overall system will maintain its integrity over long periods of time. Several radioactive waste management organisations are siting and designing deep geological repositories using a robust disposal system that incorporates simple features, for which there is practical experience, and which are acted upon by well-understood processes. By avoiding complex features and phenomena, the engineering performance and safety of these repository systems are simpler to evaluate. Also, selection of repository sites in regions with no resources of exceptional value can reduce the likelihood of future human intrusion.

In addition, many waste management organisations have programmes that actively demonstrate the technology for disposal of radioactive waste, for example surface laboratories and **U**nderground **R**esearch **L**aboratories (URLs), which demonstrate the feasibility of the disposal system and build confidence that the disposal system can be implemented with readily-achievable and demonstrable technologies. The majority of NEA Member countries consider that the development of URLs have benefits beyond those connected with R&D. Making those facilities available for stakeholder visits will also help to build confidence in the disposal project.

Multi-barrier system

One of the most important features for deep geologic disposal is a repository design based on a multi-barrier system. After closure, deep geologic repositories are "passive" systems designed to function for very long periods of time, and as such the barriers cannot be completely independent. However, a deficiency in one barrier should not significantly jeopardise the long-term safety of the entire system. Generally, the barriers consist of a series of physical components that contribute to the containment and isolation of the waste, protect the waste from man and the environment and prevent or delay the migration of radionuclides and other contaminants from the waste to the accessible environment.

Examples of barriers to transport may include:

- low-solubility waste form (particularly for vitrified high-level waste);
- fuel cladding (for spent fuel);
- long-lived container vessel with structural support to withstand stresses;
- diffusion-controlling buffer material;
- backfill materials and repository seals with favourable chemical properties; and
- low-permeability host rock with stable geochemical and mechanical properties.

Not all of these barriers will be relevant for all disposal systems and the relative importance of each barrier will depend on the specific disposal system. For example, some repository designs include an over-design of the engineered barrier system (for example, massive over-packs or excess corrosion material and buffer thickness) to account for uncertainty in barrier performance and to provide an additional margin to meet regulatory compliance, whereas others may rely more on maintaining favourable chemical conditions in the near field and on the performance of the geosphere.

A "multi-barrier" system is common to all disposal systems represented within IPAG, however its exact definition can vary from country to country. For example, most countries consider that a barrier is a physical obstruction, such as an engineered barrier or the geosphere. However, some countries expand the definition to include physical and chemical processes that inhibit or delay the release or migration of radionuclides. Therefore, ***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.***

There are essentially three approaches to exploring the adequacy of a multi-barrier system:

- The evaluation of the barrier effectiveness under a given scenario (using results from radionuclide release and transport calculations);
- The exploration of the evolution of the barriers (including FEP and scenario analyses) to investigate how the safety functions of the barriers may change over time; and

- The exploration of the consequences of one or more barriers being less effective (or failing) without necessarily explaining how the situation could occur. These calculations are sometimes referred to as "what-if " calculations.

IPAG-3 found that most safety cases and IPAs used all three approaches, and that together they typically constituted the major part of the IPA. For example, barrier effectiveness was evaluated by assessing the qualitative performance of each barrier separately in terms of the radionuclides that would be contained by that barrier as a function of barrier properties, and by undertaking a series of calculations to describe how different barriers contribute to isolation and safety. Table 3 summarises the types of scenarios that were analysed in the different safety cases and IPAs considered within IPAG-3 where barriers were assumed to be less effective than anticipated, or non-existent.

Table 3. **Examples of scenarios where barriers were assumed to be less effective than anticipated, or non-existent**

Barrier	Scenario
Waste matrix	• All of the spent fuel is exposed as soon as the waste package fails - no credit is taken for the fuel cladding • Fast fuel degradation • Fraction of radionuclides released instantaneously is increased
Canister/ Container	• Initial defect (small hole) • Early failure (no retention for some canisters) • Massive failure (no retention for all canisters)
Buffer	• Conservative (i.e. low) retention values • Unlimited solubility • Reduced buffer thickness (due to degradation) • Buffer acts as a mixing tank with through flow
Seals	• Increased permeability
Geosphere	• The disposal vault is located nearer to or farther from a fracture zone. • Increased permeability • Short travel times • Very high flows • "By-pass" (i.e. total neglect of retention in geosphere) • A major post-glacial rock movement hits the repository at 30 000 years, breaks canisters, displaces bentonite, enhances flow and transport, and brings about oxidising conditions in the whole near field and geosphere • Total loss of geosphere barrier as a result of erosion or extensive human intrusion

Comparisons with natural analogues

Current repository designs make use of well-understood materials such as iron and copper for containers and clay- and cement-based materials for backfill and seals. Extensive scientific data and information are available on the properties, long-term durability and degradation processes for these materials. Also, historical data and, in some cases, natural analogues are available that can contribute to the assessment of the long-term performance of these materials. Most waste management organisations have on-going research and development programmes to further study barrier material properties and characteristics, and thereby complement the general knowledge regarding the long-term properties of these materials. For example, addressing long-term strength and corrosion properties of the waste canisters, the evolution of the buffer materials during resaturation and the long-term evolution of ground water composition.

For most organisations, the demonstration of the effectiveness of the barriers rests on the results of experiments and measured data where possible. Qualitative arguments are also used to complement the quantitative information and arguments. For instance, natural analogue data has been used in the development of source-term models, and qualitative information and analogues have been used as supporting arguments for the performance of engineered barriers.

3.2 Confidence in the data and knowledge of the disposal system

Many of the challenges of developing a safety case and its supporting IPA derive from the fact that the performance of the disposal system needs to be demonstrated over tens-of-thousands of years and longer. There is certainty regarding some key aspects of the concept of deep geological disposal, such as the decay of radionuclides with time. However, there will inevitably be uncertainties regarding phenomena and data over such time scales, such as uncertainty regarding the future course of events external to the repository and the long-term evolution of repository materials. The uncertainty over the evolution of repository materials is dependent on the extent of available knowledge of the material properties, both as regards to the processes taking place and the conditions prevailing at the time of closure of the repository.

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.. The overall safety of the repository system will be more strongly affected by some uncertainties than others, and IPAG-3 participants noted that it is beneficial to try to identify and address such sensitivities at an early stage in developing the repository system concept. Generally, the higher the margins of safety in barrier performance, the less stringent are the demands on the precision of the associated data. In other words, data acquisition is likely to be guided by the need to improve confidence in specific aspects of the performance of the disposal system. Therefore the development of an IPA can provide important inputs to the direction of research programmes.

The calculation of the temporal evolution of a repository system relies on a multitude of parameters describing the properties of the materials involved. Much of these data are derived from experimental observation during site characterisation or in laboratory studies. The IPAG-3 responses clearly indicate that most repository programmes support extensive research and development activities. The necessity of a good scientific understanding of the repository system is thus fully recognised by IPAG-3.

Site characterisation is needed to confirm that the explored site has properties suitable for the repository. The site characterisation work also contributes to a conceptual understanding of the features and processes existing and occurring in and around the repository. A sufficient understanding of the present state and the previous evolution of the site will be dependent on the quality both of the available data and its interpretation. To avoid the potential pitfalls of misinterpretation or oversight, it will be necessary to bring together a team of experts covering a wide range of scientific disciplines. IPAG-3 participants particularly noted paleohydrogeological data as one possible source of information on transport mechanisms over very long time scales. A further observation was that confidence in the general understanding of the disposal system could be enhanced if the conclusions on long-term behaviour are compatible with observed data from natural analogues.

The understanding of the site and its processes is an important input into any attempt to assess future states of the system and is an essential prerequisite for numerical modelling of the ongoing processes for the purpose of performance assessment. In applying the knowledge base to the prediction of performance, a sound judgement of the quality of the research results and data is required. On the other hand, the safety of the repository is not affected by all the minute details of the future development of the site. A complete understanding of a site and its properties is indeed unattainable, but also unnecessary. Uncertainties are acceptable as long as their implications can be bounded. The safety case and its supporting IPA should explain the extent to which this can be achieved, for example by using some of the arguments presented later in this chapter.

Confidence in the data employed in the Safety case rests on the assurance that the research work has been properly carried out and the data has been correctly understood and interpreted within the performance assessment. Therefore it is essential to have traceable documentation of all data and clear records of their use, forming the basis of a thorough quality control system that builds confidence in data. The data quality control system should also provide auditability and justification for any subsequent changes in the data used in a safety analysis, for example where new improved data become available. It should also demonstrate how any potentially conflicting data are reconciled or handled. Some IPAG-3 participants mentioned systematic methods for data housekeeping as indispensable tools for achieving confidence in data.

Not all data are generated under the auspices of a repository programme. Most repository design principles rest upon established scientific understanding and fundamental relations such as conservation of mass and thermodynamics. Some IPAG-3 participants remarked that confidence in the quality of data and their interpretation can be enhanced by using data from a broader base, for example independent data collected by groups not directly connected with the repository development programme, or data derived from different measurement techniques. A broader database such as this may not always be possible and may be more likely to be available for data that are less site-specific. It is recommended that all available relevant data sources be explored and utilised, or at least reconciled with the data used in the IPA.

Considering the time-span over which a repository project is developed, as well as its complexity, it is important that clear records are kept of all important decisions and their basis. This includes decisions on the design and siting of the repository, the planning and implementation of the research programme, interpretation of observed data, the development of conceptual models and the representation of those conceptual models within the IPA. ***It is recommended that key assumptions and their justification are clearly stated within a dedicated section of the IPA documentation***. As an aid to confidence building, this documentation should also document where any assumptions are conservative, as these assumptions represent “safety reserves”, and will contribute to the over estimation of overall impacts (See also similar statements made in IPAG-2 [NEA, 2000-a]).

3.3 Confidence in the assessment approach

IPAG-3 participants noted that there is broad, international consensus on the general approach to conducting an IPA, emphasising this could help to build confidence in the specific approach being adopted.

A safety assessment should be conducted within an auditable framework, consistent with a regulatory framework that is clear and accepted by stakeholders. The assessment methodology should be systematic and logical, making it clear what features, events and processes (FEPs) have been considered and the justification for excluding any FEPs from consideration. Most participants in

IPAG-3 use FEP lists of some kind as a starting point for an assessment and several are moving towards using more detailed FEP analyses to identify a comprehensive set of scenarios to represent the potential evolution of the repository system. Others consider “best estimate” and “worst case” scenarios, but there may be difficulty in agreeing with stakeholders on what constitutes a “worst case”. Publishing FEP lists and seeking feedback from stakeholders of any “missing FEPs” was seen as an important element in demonstrating a comprehensive treatment of all relevant FEPs, especially when coupled with a systematic approach to demonstrate how each FEP is represented in the assessment models.

A repository is developed in stages. Original design concepts are gradually transferred into engineering proposals. Sites are selected and then explored from the surface, via boreholes and finally underground. The assessment approach should also be sufficiently flexible to allow the incorporation of any new data or understanding. All IPAG-3 participants adopt ***an iterative approach*** to the development of an IPA, continually seeking improvements in approach, data and models. Within this iterative framework, it is important to demonstrate how each assessment cycle builds upon the one before. The fact that a suite of assessments provides consistent results and conclusions over a number of iteration cycles helps to build confidence in the maturing understanding of what really determines the overall safety of the system.

Quality assurance procedures are an important part of building confidence in the assessment approach, and in particular, as a means of tracking data inputs and information sources to the IPA documentation. Open publication of Safety cases and IPAs was widely held as essential, ideally in a transparent, hierarchical presentation that can be accessed by a range of stakeholders. Some IPAG-3 participants felt that agreed standardised report formats might be beneficial.

Peer review, both internal and external, is also a major factor in building confidence in the overall approach. ***When publishing a safety case and IPA, it is recommended that there is a clear statement of the extent to which the work has been reviewed and by whom***.

3.4 Confidence in the IPA models

An IPA should present a logical chain of technical arguments, demonstrating sound and sufficient scientific understanding. It should clearly state the basis for confidence in the models used and the results obtained, i.e. explaining why the results are appropriate for decision making. This could include an explanation of why the IPA results are intuitive and consistent with the understanding of the overall disposal system, and how independent observations or pilot-scale or in-situ experiments support them.

Confidence in IPA models requires both confidence that the models are representing all relevant FEPs and that they are capable of assessing the performance of the repository system with sufficient accuracy or conservativeness. An IPA should therefore clearly demonstrate how the model requirements have been derived from FEPs analysis studies and how they have been constructed on the basis of data and understanding. Where appropriate it may be necessary to consider alternative conceptual models that are supported by the available data.

Modelling approaches

The modelling approach should be clear and transparent. A model hierarchy, with models for specific detailed processes feeding into less detailed repository system models, can support transparency in the modelling approach. Such an approach can also be used to demonstrate how individual FEPs contribute to the overall performance measures and the impact of any simplifying assumptions.

The use of simple models, for example analytical "insight" models, which capture the key physical and chemical processes and help to build understanding of repository system performance, can be used to give confidence in detailed, complex models. If different modelling techniques can be shown to give similar results, this also builds confidence in the modelling results. Several IPAG-3 participants mentioned the value of verification of numerical modelling by comparison with simple analytical models, solutions of test problems and comparisons of results from different methods used to solve the same problem. One respondent also mentioned that confidence in the adequacy of transport models could be derived from the observation that continued field-testing has not revealed any new mechanisms requiring inclusion.

Other strategies employed for building confidence in IPAs models include participating in international model comparison exercises, using models to predict measurable parameters (for example calculating ground water return times which can be shown to be consistent with geochemical measurements), and comparisons of results with natural analogues and using paleohydrogeological data (if a model can reconstruct and explain past conditions, or provide a consistent and integrated description of present conditions, this gives more confidence that it can be used for assessing future conditions).

Roles of natural analogue and paleohydrogeological studies in modelling

Most IPAG-3 participants use natural analogue or paleohydrogeological arguments in their IPAs, and a number of different approaches were identified. Some use natural analogues to bound uncertainties, for example natural analogue data have been used to constrain radionuclide solubilities. In other examples, natural analogues have been used to investigate specific processes and mechanisms, to derive confidence in experimental data and models for radionuclide transport and to enhance understanding and confidence in the operation of features and processes over time scales that are unattainable in experiments.

Specific examples of the use of natural analogues cited by IPAG-3 participants include:

- Investigations of natural uranium ore deposits and observations from Cigar Lake and Oklo have been used to support the belief that uranium oxide and many of its fission products could be effectively immobilised for billions of years in certain geochemical environments;
- Ancient burial tombs in China and Japan have been used as archaeological analogues for the long-term performance of engineered roof structures;
- Long-term corrosion properties of steel and copper have been demonstrated by reference to archaeological artefacts;
- The long-term stability of bentonite has been confirmed by the observation of little or no mineralogical change in montmorillonite-rich sediments;
- The corrosion resistance of the glass high-level waste matrix can be determined by comparison with low corrosion rates of natural basalt and old anthropogenic glasses;
- The low solubility/immobility of certain elements, for example uranium and thorium, has been supported by measurements of rock minerals and adjacent ground waters; and
- Investigations of ancient burial grounds and modern landfills have been used to provide information on the degradation of cellulosic materials.

IPAG-3 participants noted that for arguments based on natural analogues, both the disposal facility site and the analogue site need to be characterised in sufficient detail to demonstrate that the analogue conditions are applicable to the disposal facility site.

Paleohydrogeology has been used to varying extents by IPAG-3 participants. For some it is seen as an intrinsic part of site characterisation and ground water modelling. For example, it has played a major role in developing ground water parameters for Yucca Mountain (Nevada, USA), and ground water chemistry has been important in constraining unsaturated zone fluxes and velocities for the site. The most common use of paleohydrogeological studies has been to try to understand and model the past geochemical and hydrogeological evolution at the proposed repository site, in particular using the isotopic signature of the ground water to indicate its isolation time since meteoric input. The migration behaviour of thorium and uranium in natural clay has also been used to show that the migration of actinides in such clays can be extremely slow. Use of paleohydrogeological information from the repository site generally enhances the understanding of the site and the credibility of the transport modelling for the future evolution of the site. While such studies may be used to constrain migration model data, it is also noted that the past residence time of ground water does not necessarily give any direct indication of the ground water transit time from the repository to the biosphere.

3.5 Confidence in the safety case and IPA analyses

Explicit treatment of uncertainties is recognised as an essential part of building confidence in the safety case and IPA analyses. Uncertainties may be associated with the input data, the models used and the future evolution of the repository system, including potential future human actions. The questionnaire responses revealed a number of suggestions for a systematic evaluation of repository system evolution taking account of uncertainties.

Managing and handling uncertainties

IPAG-3 considers it important to have a clear strategy for dealing with uncertainties. This strategy should be explained within the safety case and its supporting IPA, demonstrating how it is followed at each step of the safety analysis. In particular, ***confidence in the analyses should be supported by clear statements on data quality, clear justifications of assumptions and a discussion of the sensitivities of the system performance to the uncertain parameters.***

Uncertainties in data may be handled by probabilistic safety assessments, which provide a systematic treatment of the effects of input parameter uncertainty. Some organisations use deterministic sensitivity studies which are helpful in exploring the impact of uncertainty in a particular parameter, and some have conducted bias audits to calculate key sensitivities to data and model assumptions. Simplifying, conservative assumptions which over-estimate repository consequences are also widely used. Some IPAG-3 participants have pointed out that the effects of such simplifications on the performance indicators needs to be well understood and be discussed in the IPA.

Systematic scenario selection based on FEP analysis is the preferred approach to handling uncertainties regarding the evolution of the repository system. This is generally based on a base, or reference, scenario and a range of variant scenarios that assess the impacts of the uncertainties in the repository evolution on long-term safety. Some organisations adopt a simplified reference scenario; others use a broad-ranging base scenario encompassing the natural or expected system evolution. Other approaches include consideration of best estimate scenarios (to demonstrate the effect of removing conservative assumptions) and worst case or “robust” scenarios (for example selecting worst-case model parameters). “What if?” scenarios have been used by some IPAG-3 participants to demonstrate the redundancy of repository barriers (primarily in disposal systems for HLW or spent fuel) or as part of quantitative sensitivity analyses to demonstrate how various system components contribute to safety (see Section A 3.2). The safety case and the IPA analyses will need to justify that the impacts of uncertainties in future states on long-term safety have been adequately considered and assessed in the scenario analysis.

Multiple safety indicators

Most IPAG-3 participants consider the total system evolution, not just radionuclide transport, and many organisations use alternative safety indicators as a complement to individual risk and dose calculations. Examples of indicators, in addition to dose rate to humans and individual risk, which have been assessed in different safety cases and IPAs produced or reviewed by IPAG-3 participants include:

- comparison of dose rate with natural background radiation levels;
- collective dose calculations;
- calculation of radionuclide fluxes from various barriers to illustrate their relative effectiveness in attenuating the releases of different radionuclides;
- comparison of radionuclide releases with the volume of natural environment that would contain the same amount of radioactivity;
- comparison of radionuclide concentrations at selected points with naturally occurring levels;
- assessment of chemical toxicity impacts by comparing estimated concentrations in the biosphere with naturally occurring concentrations and with the environmental increment;
- calculation of dose rates to biota or ecological risk assessments for specific non-human biota at the site;
- calculation of the time scales for which the various barriers provide isolation, for example the time over which the engineered barriers isolate the waste and ground water travel times;
- the fate of specific radionuclides, that is describing where in the engineered system or on the migration path they decay;
- calculation of the time evolution of selected radionuclides in different components of the repository system;
- calculation of the fractions of the initial inventory which reach the geosphere and biosphere;
- consideration of the spatial distribution of radiotoxicity between barrier components as a function of time; and
- making comparisons with the IAEA [1996] proposed clearance levels for removal of low-level radioactive material from regulatory control.

The most commonly used alternative performance indicators are radionuclide fluxes from barriers within the repository system. Some safety cases and IPAs also consider radiological risks to non-human species, the potential impact on ecological conditions and the effect of non-radiological contaminants from a repository on ground water quality. Several organisations, which do not currently use alternative indicators, stated that they were planning to incorporate them into their next assessment, implying a growing interest in this area.

Multiple lines of reasoning

Multiple lines of reasoning are a set of complementary arguments that use different approaches or sources of evidence to build confidence in IPA analyses. Both qualitative and quantitative lines of reasoning may be used, including scoping and bounding calculations, natural analogues and a variety of safety indicators. A line of reasoning does not have to address all aspects of safety, nor does it have to be fully independent of other lines of reasoning. One particular value of the use of multiple lines of reasoning is that different arguments may be more meaningful to different audiences.

The appropriate types of arguments to use will depend upon the context. Examples quoted in the IPAG-3 questionnaire include the following, many of which have been discussed in earlier sections of this chapter:

- qualitative arguments that emphasise the robust and achievable nature of the repository concept, in particular the use of well-understood materials;
- for high-level waste/spent fuel disposal systems, arguments that demonstrate waste canister integrity for a very long time under expected repository evolution conditions;
- explaining where there are reserves of safety in the IPA analysis, for example where safety-enhancing features, events and processes have been neglected in the IPA and indicating their likely impact on the repository performance measures;
- assessment of consequences of assumed barrier failures/deficiencies, that is explorations of the redundancy in the multiple barrier system;
- use of simple insight models in parallel with more complex assessment models to improve model transparency and assist in model verification;
- paleohydrogeological arguments, such as the study of the behaviour and migration of naturally occurring radionuclides or other relevant elements at the investigated site (see also Section A.4.2),
- arguments based on the use of natural analogues (for specific examples see Section A4.2);
- alternative safety indicators (for example ecological risk assessments, impacts of releases of non-radioactive contaminants on ground water quality, relating calculated doses to levels of natural background radiation – see also Section A.4.3);
- including simple, but quantitative, examples to provide a perspective on the hazard represented by the waste as a function of time;
- for low-level radioactive waste disposal facilities, arguments that the majority of the disposal inventory is short-lived and will decay whilst contained within the repository vaults;
- comparisons with other IPA studies and demonstration of consistency with the developing international consensus on how to perform IPAs.

The IPAG-3 questionnaire revealed some interesting views from regulators on the use of multiple lines of reasoning. Several regulators noted that such arguments had been deficient in the IPAs they reviewed. Generally, regulators encouraged the use of alternative lines of reasoning, but without specifying how they should be constructed. Some IPAG-3 members also noted that qualitative arguments might be less open to criticism, as they tend to receive few negative comments from reviewers, in contrast to numerous criticisms regarding quantitative methods, models and data. In particular, reasoned arguments that cover the longer time frames of repository performance seem to be well received.

3.6 Confidence via feedback to design and site characterisation

The purpose of developing a safety case and its supporting IPA is not only to provide a robust demonstration that safety can be achieved. As a part of the safety strategy, IPA modelling and subsequent analyses provide the capability to review and update assumptions, data and models, as well as to consider changes to design options to improve the disposal system. In particular, the IPA is needed to check whether suggested design modifications or measured properties of the explored potential disposal site still result in an overall safe system. Iterative feedback between an IPA and the development of the disposal system design and the characterisation of the disposal site can make an important contribution to confidence in the quality and the safety of the system as it is finally implemented. The statement of confidence in a safety case should include recognition of the resulting improvements in the understanding of the disposal system and the quality of the assessment approach and analyses.

IPA modelling allows ranking of the main factors determining the disposal system performance, and thus helps to identify and prioritise research programmes. The weight of uncertainty in the intermediate or the final results can be reduced by improving knowledge for those models, parameters or data which are the most important in terms of their impact on the evaluated safety. Based on this improved knowledge, a new proposal of options for the repository system design or a new set of IPA calculations (a new iteration) can be performed. At each stage in the development of a safety case and IPA, the benefit of undertaking further research can be assessed. Such an iterative process is part of the overall confidence-building approach.

If, for a given design, appropriate scientific research and site investigations are unable to reduce uncertainties below the required level, the design of the disposal system may be adjusted or modified in order to allow compliance with safety requirements. A new IPA modelling iteration would then be performed based on the new design. The IPA process thus benefits from the inclusion of feedback into the next iteration, for example, via improved data quality and models, and/or improved disposal system design. This iterative feedback, between IPA analysis and disposal system design, acts as an important factor in building confidence in the disposal system and the safety case and IPA.

While IPAG-3 did not reveal many examples of confidence building via feedback in existing safety cases and IPAs, the compilation of questionnaire responses in Appendix A shows that several organisations have plans to make better use of feedback in future work.

4. FINAL CONSIDERATIONS

4.1 The IPAG-3 experience

The value of IPAG-3 was reflected in the number of organisations that participated, the quality of the questionnaire answers submitted, and the timely inputs to the preparation of this report. Participation has grown in each successive phase of IPAG, from ten organisations in Phase 1 to twenty organisations in Phase 3. Further, the topics and issues examined have become progressively more conceptual and subjective through the three IPAG phases. Because of these dynamics, the implementation of the IPAG approach, which consists of collecting information based on existing safety cases, IPAs and reviews through the use of a questionnaire, and discussing and analysing this information within the full working group, was especially challenging for Phase 3.

Nevertheless, IPAG-3 provided a useful forum for participants to become aware of the various approaches and arguments that have been used to establish and communicate confidence in safety and the overall results of IPAs, and to gain first-hand knowledge of the experiences of other organisations in developing and communicating confidence arguments.

4.2 Comparison of the findings of IPAG-3 with those from IPAG-1 and IPAG-2, and with the NEA Confidence Document

A number of the topics and issues considered in IPAG-3 had also been addressed in the first two phases of IPAG [NEA, 1997 and NEA, 2000-a]. These included the multi-barrier concept, biosphere issues, and the use of multiple lines of reasoning, natural analogues and paleohydrogeology in making the safety case. The IPAG-3 observations and recommendations for these topics build and elaborate on the findings of IPAG-1 and IPAG-2.

IPAG-3 did however, conclude that one of the IPAG-2 recommendations on the multi-barrier concept would not be readily achievable. IPAG-2 recommended that a definition be developed for the multi-barrier concept that builds upon the literal meaning of “more than one barrier”, and captures the notion of the various passive barriers each contributing to safety and acting together in a complementary fashion to provide a certain degree of redundancy. IPAG-3 participants noted that there are cultural differences in how the concept is viewed, and thus the exact definition for the concept will vary from country to country. For example, most countries consider that a barrier is a physical obstruction, such as an engineered barrier or the geosphere. However, some countries expand the definition to include physical and chemical processes that inhibit or delay the release or migration of radionuclides. As such, IPAG-3 recommends that implementers clearly define what is meant by the multi-barrier concept in their safety case, including any functional requirements for their multi-barrier system. As noted in Section 3.1, approaches and techniques are available for assessing the adequacy of a multi-barrier system.

The NEA Confidence Document [NEA, 1999] proposed a framework for describing the various concepts related to the development of confidence in the long-term safety of deep geologic repositories, and the approaches used to evaluate, enhance and communicate confidence. The IPAG-3 questionnaire contained a number of questions that were aimed at finding examples and confirmation of the concepts and approaches discussed in the Confidence Document. The breadth in the types of confidence arguments identified in the various safety cases studied in IPAG-3 illustrates the overall concept of confidence building described in the Confidence Document. In particular, as summarized in Table 2, confidence arguments were identified for a number of different aspects of a deep geologic disposal system and the associated assessment of long-term safety. Finding examples of confidence building through iterative assessment cycles proved more challenging, as few programmes have progressed through enough assessment cycles for a specific disposal facility or concept to fully illustrate this process. Also, regarding robustness, the Confidence Document suggested that robustness arguments could be categorized as pertaining to either "intrinsic robustness" or "engineered robustness". As discussed in Section A5 of Appendix A, a number of examples of robustness in disposal systems were identified; however, categorizing the examples as "intrinsic" or "engineered" was not straightforward. As such, the distinction between "intrinsic" and "engineered" robustness may not be sufficient to warrant the use of the two different terms.

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 NEA Confidence Document was forward-looking toward the development of more integrated strategies. The further development of these strategies for managing uncertainties and building confidence in long-term safety will be an important item of work of the IGSC. Practical insight will be obtained from the reviews of ongoing and future safety studies on behalf of different stakeholders.

5. REFERENCES

IAEA, 1996, Clearance Levels for Radionuclides in Solid Materials – Application of Exemption Principles – Interim Report for Comment, International Atomic Energy Agency, Vienna, January 1996.

NEA, 1997, Lessons Learnt from Ten Performance Assessment Studies. OECD Nuclear Energy Agency, Paris, 1997.

NEA, 1999, Confidence in the Long-term Safety of Deep Geological Repositories. Its development and Communication, OECD Nuclear Energy Agency, Paris, 1999.

NEA, 2000-a, Regulatory Reviews of Assessments of Deep Geologic Repositories, Lessons Learnt, OECD Nuclear Energy Agency, Paris, 2000.

NEA, 2000-b, Stakeholder Confidence and radioactive waste disposal, Workshop proceedings, Paris France 28-31 August 2000; OECD Nuclear Energy Agency, Paris 2000.

Appendix A

THE COMPILATION OF THE QUESTIONNAIRE ANSWERS

TABLE OF CONTENTS
Appendix A

A1. Introduction 47

A2. General approach – case studies 48

A2.1 Context of the IPA 48
  A2.1.1 Stage of repository development, goal of IPA and intended audience.......... 48

A2.2 Description of overall approach and individual arguments to evaluate or demonstrate confidence 52
  A2.2.1 Overall approach used and individual arguments made 52
  A2.2.2 Information used to support the arguments 56
  A2.2.3 Was there an overall assessment of confidence?.. 58

A2.3 Communication of confidence arguments 58
  A2.3.1 Position of arguments in the IPA documentation.. 58
  A2.3.2 Are all confidence statements published? 59
  A2.3.3 Other presentational media.. 60

A2.4 Feedback on confidence arguments 61
  A2.4.1 Type of feedback received.. 61
  A2.4.2. New issues as a result of review.. 63

A2.5 Retrospective assessment of the overall approach and arguments used to build confidence.. 64
  A2.5.1 Additional confidence arguments that could have been used........................ 64
  A2.5.2 Preferred arguments which could not be made 66
  A2.5.3 Could repository design or site characterisation work been better designed to support IPA?.. 67

A2.6 Activities to aid confidence building in future IPAs.. 68

A2.7 Other aspects which contributed to overall confidence 71

A3. Demonstrating the adequacy of barriers and multi-barrier systems 73

A3.1 Definition of a barrier and the multi-barrier concept.. 73
  A3.1.1 How do you define a barrier?.. 73
  A3.1.2 Is the barrier definition stated in the IPA?.. 74
  A3.1.3 Definition of the multiple barrier concept 75
  A3.1.4 Definition stated in the IPA? 76
  A3.1.5 Purpose and minimum requirements for a multi-barrier system 76

A3.2 Evaluating the adequacy of a multi-barrier system 78
A3.2.1 Means of evaluation 78
A3.2.2 Description of assumed barrier failures 79

A4. Supporting arguments 81

A4.1 Multiple lines of reasoning 81
A4.1.1 Use in IPAs 81
A4.1.2 Type of arguments used 82
A4.1.3 Overall conclusions and benefits from making the arguments 84
A4.1.4 Arguments of potentially questionable value 85

A4.2 Natural analogues and/or paleohydrology 86
A4.2.1 Were natural analogues or paleogydrology arguments used? 86
A4.2.2 Type of arguments and analyses 86
A4.2.3 Added value of natural analogues 88

A4.3 Additional indicators 90

A4.4 Biosphere considerations 92
A4.4.1 Representation and its adequacy 92
A4.4.2 Is the biosphere a barrier? 93

A5. Demonstrating the robustness of the system or components of the system 95

A5.1 Specific examples of robustness 95

A5.2 Influence on the complexities in assessment models and the data acquisition needs 98

A5.3 How robustness was communicated 99

A6. Building confidence through iterative assessment cycles 100

A6.1 Impacts of the assessment of the confidence level of the safety case 100

A6.2 Examples of the interplay between PA/SA and the technological development of the repository 102
A6.2.1 What has mostly driven design changes in your programme? 102
A6.2.2 What has mostly driven site selection in your programme? 103
A6.2.3 Siting criteria 104
A6.2.4 Use of FEPs list to guide siting? 105

A7. References 107

A1. INTRODUCTION

The approaches and arguments used to establish confidence in long-term safety and the overall results of Integrated Performance Assessments (IPAs) are the focus of Phase 3 of the Working Group on Integrated Performance Assessments of Deep Repositories (IPAG-3). The working group prepared a questionnaire in order to collect information to prepare a progress report to RWMC and IGSC on the state of the art of obtaining, presenting and demonstrating confidence in long-term safety, and make recommendations on future directions and initiatives for improving confidence. The following document compiles the answers to this questionnaire.

Answers have been received from 20 organisations (see Table A-1) representing both implementing organisations and regulatory authorities in 12 countries. These organisations have participated in the preparation or review of an IPA or IPA-related document.

The compilation is structured in the same way as the questionnaire, with five sets of questions under the themes:

- A – Case studies
- B – Demonstrating the adequacy of barriers and multi-barrier systems
- C – Supporting arguments
- D – Demonstrating the robustness of the system or components of the system
- E – Building confidence through iterative assessment cycles

Some detailed questions in the questionnaire may, however, be combined under a single heading.

The compilation is generally divided into a short introductory observation section followed by a compilation of answers given. For simplicity, in the latter the different respondents are identified by their organisation acronyms even if it is understood that answers are given by staff and may not necessarily represent the full official standpoints of the organisations. It needs to be understood that the level of complexity in answers varies between respondents. It could well be that confidence arguments are made, which have not been listed by the questionnaire respondents, as they are more or less taken for granted. If an organisation is not mentioned in connection to a specific approach this does not necessarily mean that the approach is not favoured by that organisation. It just reflects that the point was not made on the questionnaire answer.

A2. GENERAL APPROACH – CASE STUDIES

This section concerns general questions on the approach to demonstrating confidence in the IPA produced or reviewed by the different participating organisations. The remaining sections contain more specific aspects of confidence building and need not be connected to the actual IPA produced or reviewed.

A2.1 Context of the IPA

A2.1.1 Stage of repository development, goal of IPA and intended audience

The responding organisations are at various stages of repository development. Several are at the generic R&D and feasibility assessment stage, others are at a stage of selecting a host rock or basic disposal system, and others are at a stage of refining their site selection options into one or a few candidates. Some programmes are at a formal licensing step for a specific repository and there are also examples where the issue is to reconfirm the basis for the existing license or to develop the decision basis for closing an existing repository.

Quite a few of the IPAs are connected to a programme decision to proceed to a next step. Examples of steps are selection of concepts, selection of sites, or license for a repository. The main goal of these IPAs (or the reviews of the IPAs) is to support the decision at stake (or for reviews to make sure that the IPA supports the decision at stake). Additional goals are to establish current state of the art, to provide guidelines for future R&D and to demonstrate IPA capability. For reviewers carrying out their own IPAs, the main goal has been to use it as a part of a review, to develop their review tools or to identify issues to emphasise in forthcoming reviews.

Most organisations list the *regulatory body* or other authorities as an intended audience, even in cases when the assessment was not a formal license application or a regulatory compliance document. Other important audiences are *the national government*, *national scientific control bodies*, *local authorities and decision makers*, *technical people working for the implementer, the waste generators (utilities etc),* and *technically qualified stakeholders and members of the public*. Most organisations also send their IPAs (or reviews of IPAs) to organisations or members of the public who express an interest to receive the IPA even if these groups may not have been the primary intended audiences.

Compilation of answers

Table A-1 displays, in a very short and condensed manner, the repository development stage and the goal of the IPAs from which the IPAG-3 participants have based their response to the questions under the heading “Case Studies”.

Table A-1. **Organisations contributing to IPAG-3, stage of development for case studies and the goal of the IPA**

Organisation	Stage of development	Reference materials and/or goal of assessment
ANDRA, France	Operation authorisation applications for URLs in 1999 (one clay site at Bure and one granitic site to be determined).	Basis for selection of initial design options and of preliminary concepts (Hoorelbecke *et al*, 1998); safety approach (Voinis *et al*, 1999); scenarios (Pierlot *et al*, 1997); design description (Ben Slimane *et al*, 1999); design choice (Ben Slimane *et al*, 1999).
AECB, Canada **(replaced by the CNSC in June 2000)**	Application for a construction licence for a near-surface disposal vault at Chalk River Laboratories for short lived (500 yrs) solid wastes.	The goal of the safety case (AECL, 1996) was to obtain a construction licence. AECB response identified issues that need to be addressed before a construction licence can be issued. (Metcalfe, 1999).
BNFL, UK	A Post-Closure safety case (PCSC) is being prepared for the Drigg near surface, low-level waste disposal facility in Cumbria, UK. A PCSC is required in September 2002 to support authorisation for continued disposal operations.	In preparation for the PCSC, BNFL has published a “Status Report on the Development of the 2002 Drigg PCSC” (BNFL, 2000). It provides a detailed description of BNFL’s intended approach for the 2002 radiological safety assessment. BNFL (2000).
BfS, Germany	Planned KONRAD repository located in an abandoned iron ore mine.	Support for license application of the KONRAD repository project. BfS (1990).
ENRESA, Spain	Concept development. IPA for a repository in a generic granite formation.	Optimise and compare conceptual facility design, to provide input to the site selection programme and to guide R&D work. Enresa (2000).
GRS-B, Germany	The Morsleben repository is an existing facility, but further operation is limited to actions for final closure.	Develop strategies for safe final closure of the repository, and to demonstrate safety by a long-term analysis. Storck *et al.* (2000).
GRS-K, Germany	Planned KONRAD repository intended for the disposal of radioactive waste with negligible heat generation.	Experts of the licensing authority prepared an expert opinion concerning the safety assessments, by examination of the license documents (here the IPA) of the applicant and preparing their own IPA. NMU (1997).

Organisation	Stage of development	Reference materials and/or goal of assessment
HSK, Switzerland	Regional studies for a HLW/ILW repository. No candidate sites, but field data exist.	See Nagra. A formal review by the regulatory authority will be needed when selecting a host rock. Review of Nagra (1994).
JNC, Japan	Generic R&D and feasibility assessment.	Demonstrate technical reliability and suitability of techniques and experience to construct a repository. Basis for selection of sites and formulation of regulations. JNC (2000).
Nagra, Switzerland	See HSK. The Kristallin-I IPA marked the end of the regional phase for the crystalline option.	Re-evaluate the host rock. Improve understanding. Identify key characteristics and ranges of parameters in order to guide site selection. To develop and test the safety assessment methodology. Nagra (1994).
UK Nirex Ltd,	Developing a generic (non site-specific) disposal concept.	Outline an approach to assessing post-closure performance by presenting a general description of the important factors determining repository performance, illustrated by application to six generic environments. Bailey and Littleboy (2000).
ONDRAF/NIRAS, Belgium	State of the art on feasibility and safety of deep disposal of high level long-lived waste every ten years.	Obtain the decision to continue the programme to step to a final phase of R&D and to start around 2010 the preparation of a preliminary safety report (PSAR). SAFIR 2 (to be published in 2001), de Preter *et al.* (1999).
OPG, Canada	The concept for disposal of Canada's nuclear fuel waste needs to be accepted before site selection will be undertaken.	Support the Environmental Impact Statement (EIS). To help assess the concept for used fuel disposal at a hypothetical site, using information from the surface and from boreholes. The IPAs forming the basis for the OPG answers are Goodwin *et al.* (1994) and Goodwin *et al.* (1996). The associated overall EIS is AECL (1994a,b).
Posiva, Finland	Decision in Principle on the need of a planned spent nuclear fuel disposal facility. Selection of one site for further development.	Support Posiva's Environmental Impact Statement and the application for the Decision in Principle for a disposal facility for spent nuclear fuel. Vieno and Nordman (1999), review in Ruokola ed (2000).

Organisation	Stage of development	Reference materials and/or goal of assessment
RAWRA, Czech Republic	Preliminary stage of repository development	Show repository function and assess the sensitivity of the system with respect to input data. (RAWRA, 1999).
SKB, Sweden	Transition from feasibility studies to site investigations (boreholes) in at least two municipalities.	Support for the transition to site investigation phase. Demonstrate feasibility of the KBS-3 concept in Sweden. Demonstrating IPA capability. SKB (1999).
SKI, Sweden	In 1988 SKB obtained a restricted operational license for the SFR repository for operational waste.	The purpose of the IPA reviewed was to obtain a license for depositing the operational waste with the highest radionuclide content in a large silo that had already been constructed. Review of SKB (1987) in SKI (1988) and of SKB (1991) in SKI (1992).
UKEA, UK	Guidance on Requirements for Authorisation.	No assessment for deep disposal is being review. Answered based on UKEA (1997) as well as Duerden *et al.* (1996), Yearsley and Sumerling (1998) and Sumerling (1999).
USDOE, USA	Yucca Mountain is the selected site for investigations. Next step will be to make a Site Recommendation.	The TSPA [1]-VA (DOE, 1998) addresses the rationale for repository development at Yucca Mountain, and the likelihood that the programme can meet its disposal safety objectives. No regulatory bearing. Additional documents used in preparing answers are DOE (1999), OCRWM (2000).
USNRC, USA	US NRC is preparing for review of license application in 2002.	To fine tune the NRC primary review tool. Use sensitivity analyses to identify important safety aspects of the system indicating were attention should be focused during the review. NRC (1999).

The intended audiences of the IPAs were:

- the Regulatory Body or other authorities (for ANDRA, ENRESA, JNC, ONDRAF/NIRAS, Posiva, RAWRA, BNFL, BfS, GRS-K, GRS-B, AECB, OPG, HSK, Nagra, SKB, SKI, USDOE);
- local authorities and decision makers (for ONDRAF/NIRAS, the Posiva EIA);

---

5. TSPA means Total System Performance Assessment.

- scientific control body etc (for ANDRA the Commission Nationale d'Evaluation, for OPG the federal government appointed Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel (OPG);
- US Congress (for USDOE);
- technical people working for the implementer: staff, R&D people, contractors (for ENRESA, JNC, Posiva, BNFL, noted by HSK, Nagra);
- the waste generators, utilities etc. (for ANDRA, ONDRAF/NIRAS, AECB review, BNFL, UKEA, SKI review);
- general technical experts, universities, technically qualified stakeholders and members of the public, etc. (for JNC, ONDRAF/NIRAS, Posiva, BNFL, UK Nirex Ltd, Nagra, SKB);
- the general public, sometimes – in a specially adopted report/brochure (for JNC, Posiva, GRS-B, Nagra).

Most organisations also send their IPA to organisations or members of the public who express an interest to receive the IPA even if these groups may not have been the primary intended audiences. (USNRC note that their IPA was not tailored to any specific audience but was made publicly available and was sent to the implementer).

A2.2 Description of overall approach and individual arguments to evaluate or demonstrate confidence

A2.2.1 Overall approach used and individual arguments made

The overall approach to demonstrate or evaluate confidence in the safety of the repository system analysed in the IPA is generally based on three main lines of reasoning. These are arguments based on technically verifiable *properties of the disposal system* (i.e. selected repository design and site), the *results of the IPA* and the confidence enhancing elements *of the IPA methodology* used.

The most important arguments concerning the disposal system are those which make it plausible that:

- the envisaged repository system is sited and designed in a way that intrinsically favours safety, as well as the quantitative evaluation of performance;
- the design is based on available or achievable technologies;
- sites exist with the desired properties.

The results of the IPA must show that future consequences comply with regulatory targets, usually expressed by several safety indicators.

The confidence in the IPA methodology rests on:

- the broad *international consensus on the general approach to* IPA and the fact that there is a strive for further improvement of this methodology;
- arguments connected to *Quality Assurance* (project quality assurance programme which conforms to recognised international standards, traceability, transparency, peer review, open publication etc);

- regulatory review and independent IPAs made by the regulators;
- the assessment of the level of confidence in the physical and chemical processes and the data used is a means to demonstrate that the IPA is based on *sound reasonable scientific understanding*;
- the *explicit treatment of uncertainties* in the IPAs;
- the systematic evaluation of the system evolution, while considering uncertainties;
- the confidence in the (numerical) models and codes used, based on the QA procedures used in developing and testing the models and codes, the results of inter-code comparisons and comparisons with analytical solutions and field tests.

Compilation of answers

Important confidence arguments are based on the technically verifiable properties of the concept (the design and/or the site). Mentioned arguments include:

- the envisaged repository system is sited and designed in a way that intrinsically favours safety, as well as the quantitative evaluation of performance (Nagra, Enresa, JNC, BfS, OPG);
- the design is based on available or achievable technologies and follows regulatory requirements (ANDRA, GRS-B, OPG);
- optimisation of facility engineering to demonstrate best practicable means are being employed to ensure radiological impacts are as low as reasonably achievable (BNFL);
- the design is based on massive engineered barriers with directly testable properties ensuring that the majority of radionuclides will decay within the repository environment (JNC, UK Nirex Ltd, Nagra);
- the design allows the safety functions to be described by simple mechanisms instead of speculative solutions with high uncertainties (ANDRA, ENRESA, OPG);
- the design is based on multiple barriers (UK Nirex Ltd, GRS-B, OPG, Nagra);
- the design takes into account future changes in the waste-package inventory (ANDRA);
- it is shown that suitable sites exist with stable geological settings (JNC).

The results of the IPA, showing that the concept will fulfil legal requirements are one key element of demonstrating the confidence in the safety of the repository system. (Only some respondents as BNFL, Nagra, GRS-K, GRS-B have made this remark, however). Some studies evaluate different safety indicators to show this compliance, for example:

- multi-criteria analysis (ANDRA);
- ensure that the estimated risk and other end points are satisfactory in relation to the regulatory criteria, and adequately account for the uncertainties and biases due, for example, to limited site information, uncertainties in waste characterisation and incomplete understanding of the relevant processes (BNFL, UKEA);
- separate analyses and criteria to evaluate dose impacts and risks to humans, risks to non-human biota and ecological conditions in the vicinity of the site, and the impacts of non-radioactive contaminants on ground water quality (in IPA reviewed by AECB);
- compare the estimated impact of LLW disposal with other sources of environmental radioactivity (BNFL);

- to highlight that the radionuclides are predominantly short-lived and will decay while being contained in the repository vaults (in IPA reviewed by SKI);
- efforts to focus on total system evolution, not only radionuclide transport (SKB).

It also noted that the results of the IPA could be used in support of an Environmental Impact Statement (Posiva, GRS-K, GRS-B, and OPG).

On an overall level the broad *international consensus on the general approach* to IPA and the fact that there is a strive for further improvement of this methodology are noted to be strong confidence arguments (ONDRAF/NIRAS, RAWRA). Evaluation of the international state of the art has been considered when reviewing the Konrad IPA (GRS-K). Also the benefits of a standardised reporting procedure are noted (even if the example given by GRS-B concerns the reporting structure of safety assessments of power plants).

Several confidence arguments are connected to *Quality Assurance*. For example:

- the use of a project quality assurance programme which conforms to recognised international standards (ISO 9001 and ISO 14001) (BNFL);
- the traceability and transparency of the IPA documentation (Posiva, JNC, GRS-K, AECB, Nagra);
- QA systems to track documents, data input and sources (JNC, GRS-B, USDOE);
- internal peer reviews, revision processes and iterations between model development, safety assessment and data collection (AECB, GRS-K, HSK, Nagra, USDOE, Posiva);
- making the IPA (or only the results of the IPA, GRS-B) and its supporting documentation available and accessible to external peer review (stakeholders, regulators, international community) by open publication (Posiva, JNC, HSK);
- competent regulatory reviews of the IPA checking the scenario analysis, scrutiny of the models, recalculation of the applicant's safety assessments, using the applicant's codes and other codes, calculations based on variations of parameters and boundary conditions, evaluation of numerical models used by the applicant (review of verification/validation reports) and by using the assumptions of the applicant as a starting point, checking whether the conclusions made by the experts of the licensing authorities were in accordance with those of the applicant (GRS-K);
- licensing authorities performing their own IPA (GRS-K);
- the inclusion of a forward programme as an integral part of the IPA to demonstrate a commitment to continual improvement of the IPA and to reducing remaining uncertainties where practicable (BNFL);
- that a suite of assessments provides coherent results over time (and iteration cycles) indicates a maturing understanding on what really determines the overall safety of the system (ONDRAF/NIRAS);

Assessing the level of confidence in the physical and chemical processes and the data used is a means to demonstrate that the IPA is based *on sound, sufficient and scientific understanding* (ANDRA, JNC, ONDRAF/NIRAS, Posiva, BNFL). Suggested means of assessing the confidence are:

- systematic scenario and model selection based on systematic FEP analysis (JNC, ONDRAF/NIRAS, BNFL, GRS-K, AECB, HSK);

- ensure that the overall scope and quality of the site investigations are sufficient to underpin quantitative modelling studies or more qualitative arguments offered (UKEA);
- systematic treatment of all processes governing repository evolution (SKB);
- using both qualitative and quantitative approaches (ANDRA, GRS-K);
- exploration of multiple sources of evidence and multiple lines of reasoning (UK Nirex Ltd, AECB, GRS-K);
- a chain of technical arguments dealing with the validity of the models and data (described in the model reports) and their representation within a disposal system model and computer code (GRS-K, OPG);
- comparing individual model components with observations from natural analogues (OPG, HSK);
- use of natural analogues for qualitative arguments to describe the very long-term behaviour of a disposal system (e.g. OPG uses comparison with impacts from uranium ore deposits and consideration of observations from Cigar Lake and Oklo);
- confidence in the adequacy of the transport models is also derived from the observation that continued field testing has not revealed any new mechanisms that need to be included (noted by HSK, Nagra);
- adoption of the most appropriate model for a specific, detailed process feeding into less detailed models of multiple processes, (UK Nirex Ltd);
- verification of the mathematical modelling by solving test problems, comparing with simple analytical models or by comparing the results of different methods solving the same problem (GRS-K, SKB, UK Nirex Ltd, ENRESA, OPG, AECB).

Also the *Quality Assurance* procedures (see previous paragraph) are by themselves important elements in demonstrating scientific credibility.

Confidence in processes and scenarios follows an understanding of the uncertainties connected with the analysis, and is built on a careful and systematic assessment of the effects of uncertainties on the safety measures. Examples of suggested confidence enhancing elements include:

- assess the uncertainty in input data and process models at all levels in the IPA (BNFL, USDOE);
- when possible use laboratory and field data when selecting input parameters to IPA, and make pessimistic assumptions when measurable data are missing (JNC, ONDRAF/NIRAS, RAWRA, UK Nirex Ltd, BfS, SKB, AECB, OPG);
- when possible use internationally reviewed databases and comparisons with previous IPAs from different countries (JNC);
- support the results and extrapolations of the performance assessment calculations with independent observations and data or specially designed pilot scale and in-situ experiments (BfS, JNC);
- ensure that sufficient depth of argument is offered to cover those uncertainties that are not amenable to quantitative analysis (UKEA).

The systematic evaluation of the system evolution, while considering uncertainties is deemed important. Examples of such a systematic analysis include:

- systematic scenario selection (see also previous points);
- selection of a base scenario with simplified initial and boundary conditions giving a step-wise increase of complexity when other scenarios are added (SKB);
- quantitative sensitivity analyses to develop an improved understanding of how the models interact, and how the various barriers contribute to safety (OPG, BfS, Nagra, SKB, USDOE);
- probabilistic analyses for a systematic treatment of the effects of input parameter uncertainty (OPG, GRS-K);
- using simplified models but constructed such that they would overestimate the consequences of the repository (noted by OPG , GRS-K and SKI);
- selection of worst case parameters for the safety case (BfS);
- analysis of "what-if scenarios" and exploration of barrier redundancy (ENRESA, ONDRAF/NIRAS, UK Nirex Ltd, Nagra, SKB).

The emphasis in the USNRC IPA was on methodology rather than on numerical results. As such, no confidence statements regarding the overall performance of the repository were made. Arguments were however made regarding the relative importance of various components and parameters for planning of future investigations and also to identify critical areas for review.

A2.2.2 Information used to support the arguments

The IPA calculations support the overall estimates of system performance and the role of different safety functions. Both transport calculations and other results are essential in the confidence building. The quantitative analyses of the IPA and its technical support from research, experiments and measurements are key information in support of the safety case, even if the qualitative information also is important.

Most of the supporting information is coming from site characterisation and the extensive research and development programmes of the different organisations. Natural or experimental evidences of processes and data are of course preferred. Qualitative arguments are based on logical reasoning and comparisons.

Ideally, the IPA report itself with the immediate supporting documentation contains the information necessary to understand the confidence in the choice of most of the parameters used in the calculations. Information on and the results of international code comparison and field testing exercises can be found in published or at least accessible literature. The information is sometimes dispersed over many scientific research reports.

Compilation of answers

The IPA calculations support the overall estimates of system performance and the role of different safety functions (BNFL, UK Nirex Ltd, GRS-B, AECB, HSK, and Nagra). Both transport calculation and other results are essential in the confidence building. Apart from RN transport calculations, the arguments are based on e.g. calculations of canister strength, of canister corrosion, of repository thermal evolution, of buffer evolution during saturation, on long term evolution of groundwater composition (SKB). SKI note that the safety case builds on results from simplified models for radionuclide retention in the waste packages and retention and diffusive transport in the engineered barriers. BNFL states that it is apparent qualitative arguments on their own are insufficient to demonstrate safety and there is a clear expectation that the safety case must include a comprehensive, quantitative radiological safety assessment including a systematic assessment of uncertainty.

Most of the supporting information is coming from the R&D programme: diffusion parameter values, corrosion rates, hydraulic conductivities. In fact, the main confidence argument here is one of a good scientific understanding (ONDRAF/NIRAS, BNFL, and UK Nirex Ltd). R&D and site investigations carried out over two decades in Finland and abroad form the basis (Posiva). If observations of nature support the approach to modelling a particular process, their influence on confidence building is always most important (BfS). GRS-K notes that the basis for the experts' IPA was the whole data set of hydrogeological and hydrogeochemical data. Due to the quality of the geological barrier system, robustness could be demonstrated within the IPA by using a range of models and data supported by natural observations. The demonstration of the effectiveness of the technical barriers rests on the results of experiments (GRS-B). The arguments rest on measured data when possible. RAWRA conservatively derived host-rock data from analogue host structures in the Czech Republic and other relevant sites around the world. For USNRC the primary source of site and design data were the DOE databases. Information from literature was freely adopted where measured data was not available. In addition some data was developed independently by the NRC and the CNWRA including natural analogue data which was used to develop one of the four source term models. AECB note the supporting arguments made use of site data, both qualitatively and quantitatively, the quantitative information on the radionuclide and contaminant inventories of the waste streams proposed for IRUS.

Qualitative arguments in the EIS are based on logical reasoning and comparisons (OPG). Qualitative arguments were mainly used to deal with "extreme events" (SKI). Qualitative information and archeological analogues were used as supporting arguments for the engineered barriers (notes by AECB).

The IPA is strongly supported by the detailed description of the disposal system and expected safety functions. All assumptions and design details salient to the safety case encapsulated in the IPA are described and documented in this series of reports and forms the basis for development of scenarios, models and databases for the IPA (JNC). The IPA report itself with the immediate supporting documentation contains the information necessary to understand the confidence in the choice of most of the parameters used in the calculations. Information on and the results of international code comparison and field testing exercises can be found in published or at least accessible literature (HSK).

The quantitative analyses in the IPAs are extensively supported by model reports, which deal with issues such as verification and validation. In many instances, these model reports rely on more detailed research (OPG). The information is sometimes dispersed over many scientific research reports (UK Nirex Ltd).

The UKEA does not specify the nature of the technical system or nature of arguments to be used. Important features of a safety concept are likely to be that the engineered design is fitted to the geological environment. The system offers both physical and chemical containment through a variety of complementary barriers and no relevant processes can be identified that will simultaneously cause all barriers to fail or seriously degrade.

A2.2.3 Was there an overall assessment of confidence?

A large group of cited IPAs contain a concluding chapter or a section called “safety case” or overall assessment of confidence. Observations aimed at confidence building on specific issues also appear at appropriate locations in the text. There is, however, a fairly large group of IPAs, which only present the individual confidence arguments on specific aspects of the IPA at the place where they are used. Of those some try to connect all the arguments by linking them to the main safety functions of the disposal system and by explaining how they contribute to the functioning of the different barriers. One respondent suggested that on overall statement of confidence is made difficult due to the varying maturity in understanding of different features, events and processes. On a more general level some respondents do not like the word “confidence statement”. You want the audience to be confident in you and being overconfident yourself may be detrimental to that.

Compilation of answers

A large group of cited (ANDRA, JNC, Posiva, HSK, Nagra and SKB) IPAs make an overall statement of confidence in a concluding chapter or a section often called “safety case ”. BNFL aims to include such a statement in the 2002 PCSC (Post-Closure safety case) with reference to the NEA “Confidence” report (NEA, 1999). Observations aimed at confidence building on specific issues also appear at appropriate locations in the text. The UKEA “Guidance on Requirements for Authorisation” (GRA) states “all the separate lines of reasoning which are mustered by the developer in support of safety will, in different ways and to different degrees, inform the regulatory decision.”

Another large group of the case studies only presents the individual confidence arguments on specific aspects of the IPA at the place where they are used. In addition, they have not put all the arguments together in one statement of confidence (ENRESA, ONDRAF/NIRAS, UK Nirex Ltd, BfS, GRS-K, and GRS-B, noted by AECB, OPG, noted by SKI, USDOE and USNRC). ONDRAF/NIRAS remarks that they tried to connect all the arguments by linking them to the main safety functions of the disposal system and by explaining how they contribute to the functioning of the different barriers. OPG remarks that in general, a systematic and consistent approach to produce an overall statement of confidence was not taken because of the varying maturity in understanding and confidence statements that could be applied to the large number of features, events and processes.

JNC also notes that confidence was further supported by the fact that power companies and other interested parties performed parallel analyses with slightly different assumptions. RAWRA notes that the assessment is shown to comply with requirements.

A2.3 Communication of confidence arguments

A2.3.1 Position of arguments in the IPA documentation

As already noted (2.2.3) several assessments both present confidence arguments at the appropriate places in the IPA and summarize them in a concluding chapter or section, sometimes called a “safety case ”. Several other IPAs basically only present their confidence arguments together with the evaluation of the different components of the disposal system to which they apply or where the bases for the arguments are given.

Some IPAs provide some confidence-related arguments already in the introduction. Examples of arguments are those regarding the treatment of uncertainties, review of legislative requirements, arguments relevant to the quality of the disposal system or a brief mentioning of the main confidence arguments.

Compilation of answers

As already noted (2.2.3) several assessments both present confidence arguments at the appropriate places in the IPA and summarize them in a concluding chapter or section, sometimes called a “safety case ” (ANDRA, JNC, Posiva, BNFL, HSK, Nagra, SKB). USDOE notes that the TSPA-VA report contains statements of uncertainty and data needs throughout, and rolls them up into a future work recommendation section. SKI notes that the confidence arguments were found throughout the entire safety report, but a small summary of the most important arguments was placed at the end of the document.

Some IPAs provide some confidence-related arguments already in the introduction. Examples of arguments are those regarding the treatment of uncertainties (ENRESA), review of legislative requirements (RAWRA) or other requirements (GRS-B). The arguments relevant to the quality of the disposal system are positioned up front in the IPA in order to provide information for justified assumptions on the disposal system to be assessed (ANDRA). Kristallin-I briefly mentions the main confidence arguments already in the introduction (Nagra).

Several of the cited IPAs basically present their confidence arguments together with the evaluation of the different components of the disposal system to which they apply or where the bases for the arguments are given (ONDRAF/NIRAS, UK Nirex Ltd, BfS, GRS-K, GRS-B, AECB, OPG, USNRC).

The UKEA has not yet examined a fully developed safety case presented by a developer.

A2.3.2 Are all confidence statements published?

Most respondents suggest that all confidence arguments have been published or will be included in the IPA report when it is published. However, in some instances the IPA reports are not publicly available. There, only parts of the arguments are available for the public.

In contrast, some note that their IPA generally include only the confidence arguments that directly bear on specific issues deemed to be most relevant at the time the reports were being written. In particular, some respondents suggest comparing repository risks with other risks may be seen as irrelevant and may be counter productive for some stakeholders.

Arguments deemed relevant later on or highlighted during review are evidently not found in the past documents. Other respondents note that some scoping calculation; mathematical model verification exercises or “back-of-the envelope” tests were never published.

Compilation of answers

Most respondents suggest that all confidence arguments are published or will be included in the IPA report when it is published (ANDRA, JNC, ONDRAF/NIRAS, Posiva, RAWRA, UK Nirex Ltd, Nagra, USDOE, USNRC). However, in some instances (BfS and GRS-B) the IPA reports are not publicly available. There, only parts of the arguments are available for the public. GRS-K notes that the arguments are part of the documentation prepared for licensing authority. They were also widely discussed during the public hearing.

In contrast, OPG notes that the IPA safety assessments and model reports generally include only the confidence arguments that directly bear on specific issues deemed to be most relevant at the time the reports were being written. Other arguments are cited in the text, but it is clear that a larger number of confidence statements were omitted from the IPAs. Also during the review, non-discussed aspects relevant to confidence building were noted. Also HSK assumes that the confidence building internal to the organization further rests on a multitude of minor facts that add up to a consistent picture. SKB notes that information on natural analogues gathered over the years was not utilised to the extent possible in the IPA report. BNFL notes that key messages that build confidence in safety are published. Some arguments have been tested internally, for example, comparisons of radiological impacts with other hazards and risks (e.g. air pollution, passive smoking, and road traffic deaths, lightning). These arguments may not be directly used in the safety case as they may be interpreted as not being relevant, e.g. comparing voluntary or “natural” risks with risks ‘imposed’ by industry. The correct balance of providing information without appearing to justify the impacts of waste disposal by comparisons with other impacts is still being developed.

Evidently some analyses are not published. ENRESA notes that some mathematical model verification exercises were not published. Some scoping calculations made by AECB were never published. However, these scoping calculations prompted questions to AECL to perform additional and now published calculations. Internally at SKI there was some concern about the relatively high sensitivity of calculated dose rates to some of the parameters and models used.

A2.3.3 Other presentational media

Quite a few IPAs, but not all, are presented, or will be presented, in brochures and newsletters intended for the general public. Many organisations have also prepared various presentation materials including slides, videos or a video-wall to be used in oral presentations to the public. The material often takes a much wider view than just the ‘performance assessment story’. The results of some IPAs are presented during public hearings.

Some organisations have developed more computer oriented information systems. Information on various levels can be found on web-sites and on CD-ROMs where databases and/or the entire assessment are available. There are also examples of more interactive media such as a “virtual repository system” or simplified but graphically advanced assessment models, which users can play and explore with.

Publication in the open literature (refereed journals) has not been practised to a large extent, but it is recognised by respondents to be potentially important.

Compilation of answers

Quite a few IPAs are presented, or will be presented, in brochures and newsletters intended for the general public (ONDRAF/NIRAS, Posiva, BfS, GRS-B, in AECB’s answer, OPG, SKB, noted by SKI, USDOE). Many organisations have also prepared various presentations of materials including slides, videos and a video-wall (ENRESA) to be used in oral presentations to the public. However, OPG notes that the AECL media for the most part took a much wider view than just the “performance assessment story” because the final results of integrated assessments did not become available until quite late in the research programme. SKI notes that the SKB brochures mostly were intended to explain how the repository was constructed, how it works during the operation and the type of waste that is placed there. Only small parts were devoted to aspects of long-term safety that mainly discussed decay of nuclides.

GRS-K notes that in the framework of the licensing procedure the Plan KONRAD was displayed publicly in 1991 and a public hearing with duration of 75 days took place in 1992/1993.

Some organisations have developed more computer oriented information systems. Some information in TILA-99 can be found on the Posiva web-site. JNC has developed a publicly available database system specific to the IPA and information relevant to the individual arguments can be accessed through the web. In addition, a “virtual repository system” was developed. This system, called GEOFUTURE 21, is a tactile “ride-like” display that is part of the public outreach activities at JNC’s community museum in Tokai-mura, Japan. The information can also be accessed on a CD-ROM. USDOE distributed to the entire TSPA-VA on a CD-ROM and it is also accessible from the Web. In addition, a Simplified Total System Performance Assessment Model (based on the VA model), which will be a fully functional model that graphically depicts how all of the components fit together, is being created.

Some organisations have not yet published much other presentational material to support the IPA (ANDRA, RAWRA, BNFL, UK Nirex Ltd, Nagra, and USNRC). However, UK Nirex Ltd notes that much effort was focused on making the report visually pleasing and using illustrations at every opportunity to assist in communication. BNFL notes that there is a need for other means of communication with the public, but the forward strategy to communicate its main findings to a wider audience is still being developed. HSK notes that the repository concept and the associated safety concept have been explained in publications intended for a general readership and Nagra notes that an edition of the “Nagra Bulletin” was issued on the disposal programme for high-level waste.

A2.4 Feedback on confidence arguments

A2.4.1 Type of feedback received

There are various experiences on reviewers’ feedback on the explicit confidence arguments presented. The values of the arguments, including statements on robustness, are appreciated but some reviewers expressed the need for more full-scale demonstrations or more realistic modelling. To the extent they were made, arguments based on multiple lines of reasoning were appreciated, at least in contact with the public. Some respondents see a clear need *for improved confidence arguments in the case for safety*, while others do not.

Some respondent see different types of feedback arising from different groups (i.e. waste generators are interested in design options, scientific bodies look at the rigorous use of data and the way associated uncertainties are taken into account and safety departments assess the qualitative and quantitative approaches for the IPA). Some reviewers obtained additional confidence in the IPA results after conducting their own scoping calculations. Regulatory feedback on IPAs can also concern the credibility of the analyses that are critical, in terms of specific areas where more information is needed in support of the modelling done.

Compilation of answers

There are various experiences on reviewers’ feedback on the explicit confidence arguments presented.

In the Posiva most reviewers acknowledge case, the robustness and very good isolation capacity of the disposal system. Full-scale demonstrations, in particular for manufacturing, sealing and QC of the copper-iron canister are requested. Reviewers also call for a more realistic modelling, especially of geosphere transport.

BfS and GRS-K note that the confidence arguments were of utmost value in the licensing procedure. During the review process they were discussed with the licensing authority and its respective consultants. GRS-K note that the main emphasis had been laid on the role of PA and uncertainties and their influences on PA.

BNFL note that in the ongoing information exchange process with the UK Environment Agency, the agency has indicated the value of a systematic approach to radiological safety assessment, especially with regard to the treatment of uncertainty.

AECB note that the multiple lines of reasoning approach and the use of alternative indicators increased confidence in the long-term safety of the proposed IRUS Disposal Facility. AECB note that their internal scoping calculations with analytical solutions gave AECB staff additional confidence in the results of the detailed analyses.

According to OPG most technically oriented stakeholders were not satisfied with the quality and completeness of all confidence arguments, but overall, were sufficiently satisfied with the disposal concept that they recommend moving from a conceptual phase of study toward siting a disposal facility. The Panel's main conclusions concerning the safety and acceptability of the AECL disposal concept is that from a technical perspective, safety of the AECL concept has been on balance adequately demonstrated for a conceptual stage of development, but from a social perspective, it has not. Thus, OPG feels that there is a need for improved confidence arguments in the case for safety, where those arguments are aimed at a broader group of stakeholders other than the technical audience.

According to ANDRA "Industrial" waste generators are interested in the methodology applied to reach conclusions concerning design options (including the way IPA results were taken into account), scientific bodies look at the rigorous use of data and the way associated uncertainties are taken into account. The latter observations is partly shared by ENRESA who notes that internal staff wish to strengthen the arguments in the support of models and experimental results obtained in the internal R&D programme. ANDRA also notes that safety departments assess the qualitative and quantitative approaches for the IPA.

USDOE notes that reviews by NWTRB and by NRC staff gave feedback on the credibility of the analyses that were critical, in terms of specific areas where more information is needed in support of the modelling done. There were few instances of these groups' recommendations not already having been captured in the self-evaluation that was reported in IPA, even if there were disagreements evident on some issues in terms of different perceptions of potential importance to safety.

JNC notes that several review groups were developed to get feedback from an important group of technically based stakeholders. Additionally, periodic international reviews of both databases / models and the overall safety assessment were held with both European and North American groups. The NEA international review was also a useful step to increase confidence in the H12 IPA.

SKI notes that the confidence arguments were generally not questioned so much, probably because they received very little attention. The experience was that the public had made up their mind at a very early stage, some were in favour and some were much against the repository. Environmental groups raised a few concrete objections of the SKB analysis.

The USNRC IPA was presented to its Advisory Committee on Nuclear Waste (ACNW). Questions were raised about some model formulations and associated parameters being overly conservative

Several organisation did not answer the questions since the IPA is not yet published or was published very recently or since or the review had not yet been completed (ONDRAF/NIRAS, UK Nirex Ltd, GRS-B, HSK Nagra, SKB).

A2.4.2 New issues as a result of review

Generally, reviews seem to open few new issues in relation to already identified outstanding issues in the interaction between implementer and regulator and in relation to the issues opened by the IPA itself. It also seems that experiences differ somewhat between organisations working with a concept over several iteration cycles and organisations presenting their concept and IPA for the first time. It is pointed out that if there are significant changes in the assumed importance level of the different barrier functions, this may create a confidence problems since reasoning and conclusions from previous assessments and reviews may not be fully valid. There is thus a need for caution of not being overconfident at early stages.

Examples of new issues being raised include those connected to:

- scenario and data selection (which time scales are relevant for different safety indictors and scenarios, what are the probabilities or what is the proof for conservatism);
- a desire to see more realism and data consistency in the IPA model assumption;
- monitoring and retrieveablity;
- possibilities of generic conclusions from site specific studies.

It was also noted that some stakeholders appear to have a desire to see scientific/technical solutions to all issues including of those depending on political or management decisions.

Compilation of answers

It is suggested (OPG) that in a sense, all confidence arguments and safety analyses raised issues with stakeholders. The answer from ANDRA refers to all feedback received from their reviewers (See A.2.4.1). However, several respondents (e.g. ENRESA, RAWRA, AECB, and USDOE) do not consider the raised issue to be “new”. AECB notes that there are outstanding issues on the confidence arguments that need to be addressed before a construction licence can be issued. USDOE notes that several places where there were existing differences of opinion between the DOE and the NRC were reiterated in their comments on the TSPA-VA.

Some respondents list some new issues. Several issues concern scenario and data selection, for example:

- the selection of appropriate time scales for safety assessment and which scenarios and alternative safety indicators are most valuable (JNC);
- lack of agreement on the probabilities of scenarios and lack of agreement that the selection of scenarios or values for parameters adequately represents “worst-case” conditions (OPG).

Some issues are connected to a desire to see more realism in the IPA model assumptions. For example reviewers noted:

- an apparent lack of consistency between groundwater transit times used in assessment and the interpreted ages of the deep groundwater (Posiva);
- a desire to see the use of more complex and realistic hydrogeological models as a means to be more confident in the results of the simpler models used before (noted by BfS, GRS-K).

Examples of other issues raised include:

- potential monitoring and retrievability activities (JNC);
- lack of agreement that the two case-specific IPAs in the Canadian example had generic applicability (OPG);
- a desire to see scientific/technical solutions to all issues including of those depending on political or management decisions (JNC).

SKI notes that in the different stages of IPAs made for the SFR there were significant changes in the assumed importance level of the different barrier functions. When such changes occur, the regulator may have difficulties to defend the reasoning and conclusions of a previous review.

Several respondents (ONDRAF/NIRAS, BNFL, UK Nirex Ltd, GRS-B, Nagra, and SKB) refrained from answering the question, as they have as yet not received any formal review on their IPA.

US NRC notes that it will use its standard of “reasonable assurance” to determine whether the licensee has demonstrated the safety of the repository. Reasonable assurance is not numerically defined and is based on the overall record presented by the licensee.

A2.5 Retrospective assessment of the overall approach and arguments used to build confidence

A2.5.1 Additional confidence arguments that could have been used

Additional confidence arguments that could have been used are essentially of the same character as the list of arguments used (see A.2.3). There is of course quite a wide spread between respondents, partly because the different IPAs already use different amounts of confidence arguments.

Some suggest that future confidence arguments would be of the same general types but would differ in detail and in the cited information to provide support to the arguments. Additional confidence arguments suggested include:

- a more developed statement on the available level of confidence in the IPA;
- better geosphere data, when they are available;
- complementary simplified analyses and bounding calculations;
- more explicit use of “what-if” scenarios and a discussion of design margin and defence in depth;
- more use of natural analogues;

- use of computer-assisted systems for scenario development and quality assurance;
- summarising all conservative assumptions in tabular format;

It is also noted that future confidence arguments will be based on feedback from reviewers.

Compilation of answers

ENRESA (and Nagra) suggest that although the confidence arguments would be of the same general types, they would differ in detail and, in particular, in the range of observations and experiments cited to lend support to model assumptions and parameter values. BfS notes that the results of three-dimensional fresh/salt water calculations (not possible at the time) could give helpful arguments. GRS-K notes that salt water calculations would be helpful to underline the conservatism of the fresh water calculations. SKB suggest they could have performed more probabilistic calculation cases, illustrating the importance of a few specific assumptions.

BfS suggests the development of confidence could be done more formally and uniform throughout the preparation of the different technical reports. Retrospectively, UK Nirex Ltd may have wished to structure the document differently to make the confidence building statements more prominent. ENRESA would like to use better geosphere data, when they are available. HSK stresses the importance of the traceability of data back to their sources. OPG notes that complementary simplified analyses and bounding calculations and more explicit use of “what-if” scenarios could have been included in the EIS and SCS. Also, more explicit use of “what-if” scenarios (OPG). USDOE notes that a discussion of design margin and defence in depth would have strengthened confidence in the models and analyses. Natural analogues could have been utilised more (Posiva, RAWRA, SKB, USDOE). JNC note that although the computer-assisted systems for scenario development and quality assurance in assessment calculations have been developed, they are not fully applied for the IPA.

AECB staff notes that it would be beneficial for proponents to summarise all conservative assumptions in tabular format, along with explanatory notes describing the degree of conservatism, and the overall effect of the conservative assumption on calculated long term impacts. All assumptions need not be conservative.

UKEA concludes that confidence in system design rests on selection of an appropriate repository concept and that confidence in estimated performance rests on a sound scientific understanding and modelling of the relevant FEPs and the ability to obtain and select appropriate data for use in the models.

SKI notes that a few radionuclide retardation mechanisms were omitted in the radionuclide transport calculations. They suggest it might have been useful to illustrate the redundancy provided by these inherent safety-enhancing features.

ANDRA notes that they have a first iteration IPA and the next step would be to consider feedback from reviewers and fine tune arguments. ENRESA states that Peer Reviews will be good when they have it. HSK notes that the confidence derived from following standard procedures and making comparisons with other IPAs is dependent on a good knowledge of different IPAs and a judgement on their adequacy to the purpose.

BNFL suggests some arguments and evidence have not been utilised because they were not yet fully developed, data collection is still ongoing or the implications have not been fully assessed. It is counterproductive to building confidence to include arguments, which have little impact or are deemed irrelevant; therefore a fairly cautious approach is taken to building the safety case.

A2.5.2 Preferred arguments which could not be made

There are a variety of arguments that would have been preferred but could not be made, but such arguments and reason for why they could not be used vary. Quite a few would like to be more site-specific, but would then need data from a selected site. Other reasons for not making preferred arguments include:

- lack of resources at time of IPA;
- new techniques, knowledge or data available today but not at the time of the IPA;
- potentially beneficial FEPs (such as the Zircaloy cladding or aspects of geosphere retention), but not incorporated due to lack of information/knowledge;
- “open questions”, where ideally arguments would have been made to show that these issues could be neglected (or handled in a defensible way), but at the time of the IPA this was not possible due to insufficient information or knowledge due e.g. to complicated physics;
- undeveloped arguments or arguments which have little impact or are deemed irrelevant.

A suggestion is made that a fairly cautious approach should be taken to build the safety case. In general, there is always going to be ongoing work that is not ready to go into the current iteration of an assessment. It is important to identify this ongoing work as part of the safety case (e.g. in the forward programme) and then build it into the next iteration.

Compilation of answers

ENRESA notes that a real site instead of a generic one, with real data, would represent a significant improvement. HSK notes that given better access to the host rock, many assumptions about its properties could have been put on a firmer ground. Also Nagra suggests that additional information from site investigations, as well as model development, may give the confidence required to allow more credit to be taken for the geosphere transport barrier.

Other arguments that would have been preferred, but could not be made include:

- information showing that the geosphere is a good transport barrier also for non- and weakly-sorbing nuclides (Posiva);
- consideration of new results from R&D, experiments etc, not available at the time of the IPA (OPG);
- better integrate repository design and site characterisation work in the safety demonstration (ONDRAF/NIRAS);
- potentially beneficial FEPs (such as the Zircaloy cladding), but not incorporated due to lack of information/knowledge (still noted to be additional qualitative arguments for safety by Nagra, OPG);
- “open questions”, where ideally arguments would have been made to show that these issues could be neglected, but at the time of the IPA this was not possible due to insufficient information (Nagra);

- a broad and clear consensus among geoscientists and other stakeholders regarding the tectonic baseline for the time scales over 100 000 years in Japan (JNC);
- a development of safety indicators and calculations of comparative test cases (RAWRA);
- a probabilistic assessment to better incorporate uncertainties even if not required by law (GRS-B);
- a greater emphasis on the Thermal-Hydrologic-Chemical (THC) and Thermal-Hydrologic-Mechanical (THM) couplings would have been helpful, but it is difficult to test these complex couplings (USDOE).

SKI notes that there will probably always be additional arguments that can be made, but for a reviewer they may do more harm than good if they are not sufficiently convincing or well explained. Quality is more important than quantity.

BNFL suggests it is counterproductive to building confidence to include arguments, which have little impact or are deemed irrelevant; therefore a fairly cautious approach should be taken to building the safety case. In general there is always going to be ongoing work which is not ready to go into the current iteration of an assessment. It is important to identify this ongoing work as part of the safety case (e.g. in the forward programme) and then build it into the next iteration.

A2.5.3 Could repository design or site characterisation work have been better designed to support IPA?

Some respondents see a need for improved site characterisation data. However, often the lack of data is explained by lack of a specific candidate site for the studied repository concept. Future site characterisation and repository construction work should be planned and executed such as to allow *in situ* observations aimed at obtaining a consistent understanding of the properties of the host rock under natural groundwater pressure and flow conditions.

There is also identified development needs concerning integration between design, site characterisation and IPA. Confidence in the overall safety of the repository system should depend on the harmonisation of the IPA, repository design and site selection / characterisation. The very long time period between initial planning, siting, operation and eventual closure of repositories should also be considered. There is a need for a periodic update of the safety case.

Compilation of answers

Some respondents see a need for improved site characterisation data. However, often the lack of data is explained by lack of a specific candidate site for the studied repository concept. ENRESA notes that they are at an initial stage, and since there are no site-specific data, it was necessary to use available general information. AECB notes that some of the technical issues raised during the review process were difficult for AECL to address based on the available historic data for the site. HSK notes that any future site characterisation and repository construction work should be planned and executed such as to allow *in situ* observations aimed at obtaining a good understanding of the properties of the host rock under natural groundwater pressure and flow conditions.

There are also identified development needs concerning integration between design, site characterisation and IPA. Nagra suggests that the relative merits of alternative designs (e.g. emplacement in boreholes drilled from tunnels, alternative canister materials, such as copper) could, in retrospect, have been considered. JNC suggests that confidence in the overall safety of the repository system should depend on the harmonisation of the IPA, repository design and site selection / characterisation. ONDRAF/NIRAS notes that the link between repository design and confidence in the safety evaluation needs to be strengthened in the future. Posiva notes that some of the shortcomings in presenting confidence arguments occurred because work on engineering design, site characterisation, PA and supporting R&D were carried out and reported in parallel by several institutions. USDOE notes that as a direct result of some of the TSPA-VA work, it was decided that greater confidence was needed, hence the design was revisited and changed to provide greater assurance of safety through more robust engineered barriers. SKI notes that since the SFR is a built repository in operation, it is somewhat late to discuss if alternative designs or site characterisation programmes would have been beneficial. However, it is still possible to affect the characteristics and the inventory of the waste types that are accepted for deposition. GRS-K notes there is a need to formalise the confidence building process for all steps in developing a repository. BNFL notes that Drigg has a 40-year operational history during which time disposal practices have changed from simple earth trenches with a low permeability clay base to engineered concrete vaults with a standardised waste form. They suggest it would be a useful learning point for other repository programmes in the planning or early operational phase to realise that what now seems state of the art may seem relatively primitive in 50 to 100 years time. Therefore, as the safety case is periodically updated during the operational phase, hindsight will always show that some things could have been done better.

A2.6 Activities to aid confidence building in future IPAs

There are several activities planned or identified aiming at improved confidence building in future IPAs.

The need for a well-defined schedule and well-defined roles of the different actors for repository development is identified. In addition, the need to identify stakeholders' expectations concerning the type of results they are seeking, enhanced interaction with the regulators and their experts and the need for regular peer reviews are acknowledged.

There may be some concept development. Some will explore new scientific and engineering concepts that may contribute to a more robust, cost-effective repository design and construction. Interaction between design, site characterisation and IPA is stressed. Evaluation of potential monitoring and retrievability may be foreseen.

There will be improved site specific data and improved use of site specific data in future IPAs. Some programmes are now at the stage to start bore hole investigations at candidate sites or even to go underground at the designated site. New experiments are also planned. Most experiments concern further exploration of proposed-engineered barriers including encapsulation technique.

There will be further model development and research aiming at process understanding. One respondent saw a need to make the scientific community aware of the importance of making large efforts to improve our knowledge in order to demonstrate that a safe disposal is achievable. Existing unresolved issues should be explored. There is still a need to improve the understanding of migration in the heterogeneous geosphere. There is also an identified need to assess coupled mechanical effects (earthquake modelling, creep movements in the rock, etc).

There are several plans for development of the IPA procedures. Some organisations still see a need to develop techniques for scenario selection. Some will pay more attention and give a more central role to the normal evolution of the disposal system and the integrity and isolation capability of the engineered barrier system. Several will also try to improve the communication of IPAs.

More safety indicators will be assessed and more qualitative arguments are planned. Generally these plans concern exploration of defence-in-depth, multiple lines of reasoning, other safety indicators, natural analogues and paleohydrogeology, and qualitative information (see remaining chapters in this compilation).

Compilation of answers

The need for a well-defined schedule and well-defined roles of the different actors for repository development is identified. ANDRA stresses the need to communicate systematically on the established process and schedule for all activities and to prove that this process and schedule are closely followed with minimum or justified changes (ANDRA). OPG notes that a waste management organisation (WMO) is being planned in Canada for long-term management of nuclear fuel wastes. The WMO responsibilities would be clearly distinct from those of the waste producers.

ANDRA stresses the need to identify precisely stakeholders' expectations concerning the types of results they are seeking taking into account organisational changes, major scientific breakthroughs and other changes. Posiva welcomes an enhanced interaction with the regulators and their experts, which was proposed by the international review team. UK Nirex Ltd is keen to identify what stakeholders would like/expect to see in an IPA and what would give them confidence in the methodology and the results. USNRC notes that the need to conduct a peer review of the TPA code was identified in building confidence in its capability for use in regulatory reviews.

A key aim for BNFL is to clearly show how the forward programme has been driven by the results of the systematic safety assessment, especially in relation to reducing those uncertainties that have the greatest impact on assessment results. In the past, the link between assessment results and the forward programme has been less clear.

There will be some concept development. JNC plans to explore new scientific and engineering concepts that may contribute to a more robust, cost-effective repository design and construction. They will also evaluate potential monitoring and retrievability activities. However, such issues are relevant in most countries and projects. Nagra will put more emphasis on the iterative process of repository planning and development and on the methodology and key elements of the IPA. RAWRA sees a need for a better communication between PA people and relevant deep geological development activities, especially barrier system development and siting.

There will be improved site specific data and improved use of site specific data in future IPAs. ENRESA will involve experts from site characterisation and R&D areas directly in the IPA. RAWRA wishes to start geological investigation with the goal to lower the number of candidate sites and to start the experiments (laboratory and field tests) in near field and far field. JNC will make use of URLs to demonstrate methodology for characterisation of the geological environment. Posiva will start underground exploration at the selected site. (SKB plan to start bore hole investigations at two or more sites – not in answer).

New experiments are planned. JNC sees the need to conduct further scale-up of engineering tests. Posiva notes that demonstration is needed of technical feasibility of the concept, in particular regarding encapsulation and repository development (the prototype repository at Äspö). UK Nirex Ltd is considering commissioning large-scale demonstration experiments in particular to build confidence in the chemical containment within the near field.

There will be further model development and research aiming at process understanding. For ANDRA priority has been given to making the scientific community aware of the importance of making large efforts to improve our knowledge in order to demonstrate that safe disposal is achievable, and that an open process with all inputs is set in place to design it. ENRESA plans to address existing unresolved issues from the past IPAs, such as gas generation and migration, hydro-thermo-mechanical coupling, etc. JNC wishes to establish consensus on long term stability of the geological environment and to confirm the longevity of the buffer over a range of possible repository conditions. ONDRAF/NIRAS wishes improve the understanding of the migration behaviour of critical radionuclides in the geological barrier. GRS-K notes that the use of arguments obtained from natural observations could be increased. GRS-B plans to investigate more natural analogues to get a better understanding of the processes related to the transport of radionuclides in the environment. Nagra sees a need for studies addressing the issue of the representation of the geosphere transport barrier. HSK notes that understanding the abstraction from the strongly heterogeneous situation in nature to the simplified transport models in more quantifiable terms would enhance the confidence in applying these same models and associated data on larger scales. They also see the need to follow up identified open questions. SKB plans to study several issues including biosphere modelling, earthquake modelling, long-term effects of creep movements in the rock, the mechanical effects of tectonic rock movements on the canister, (e.g. creep effects in the copper shell), general function of the backfill, erosion of buffer and backfill under different climatic conditions, the early hydromechanical evolution of the canister-buffer gap, models for hydrology and radionuclide transport on a detailed scale around deposition holes to permit optimal choices of deposition holes, and fuel dissolution. USDOE notes that a major goal of the TSPA-VA was to identify R&D areas. The IPA by USNRC identified items for R&D based on their importance to overall performance, the magnitude of uncertainty in such items, and the possibility for reducing such uncertainty. SKI wishes more detailed radionuclide transport calculations and a more detailed scenario analysis that more comprehensively illustrates the probable range of dose or risk for various scenarios (from realistic to conservative). SKI notes that general topics that will continue to be important research topics are radionuclide retardation in different environments, long-term resistance of engineered barriers and the effects of climate evolution.

There are several plans for development of IPA procedures. JNC wishes to develop scenario selection, the stylised approach, biosphere modelling, and treatment of future human activities and will implement a systematic FEP-driven scenario approach to the organisation of the IPA. They also wish to formalise an approach to the inclusion of sensitivity and uncertainty assessments. SKI has similar wishes for the updated SFR assessment, but SKI also wants to see "what-if" calculation cases to illustrate the expected behaviour of individual barrier functions, the redundancy of safety enhancing features of the repository concept and finally the level of conservatism of the dose estimates. ENRESA will carry out both probabilistic and deterministic calculations and use alternative models and calculation tools. Posiva will pay more attention and give a more central role given to the normal evolution of the disposal system and the integrity and isolation capability of the engineered barrier system. UK Nirex Ltd will put greater emphasis on discussing the period of time immediately following waste emplacement, for which there is containment of radionuclides. SKB sees a need for a more systematic choice of scenarios. USDOE plans to explore potentially disruptive processes and events.

Some respondents also see a need for improved communication of IPAs. JNC plans to develop computer visualisations of simulation results of future behaviour of the repository system. UK Nirex Ltd has identified communication and clarity as important goals for future assessments.

More safety indicators will be assessed and more qualitative arguments are planned. BfS notes that the use of natural safety indicators could be increased and supports a project on natural geochemical fluxes and concentrations and their use as indicators of repository safety. GRS-K notes that the use of arguments obtained from natural observations as well as the use of natural safety indicators could be increased. GRS-B positively awaits the development of criteria for repositories. Nagra suggests that in future IPA documentation, besides quantitative arguments, more attention and room will be given also to qualitative arguments highlighting the intrinsic safety of the repository system. AECB staff suggests that the use of multiple lines of reasoning, other safety indicators, natural analogues and paleohydrogeology, and qualitative information in IPAs needs to be increased and enhanced to make a more convincing case for long-term safety. USDOE stresses the need to explore margins of safety, and defence-in-depth, and to use insights from natural analogues.

The technical requirements issued by UKEA which are most relevant to confidence in safety case concern the environmental radioactivity, multiple-factor safety case, monitoring, and system of records and Quality Assurance.

A2.7 Other aspects which contributed to overall confidence

Competent review, with frequent interaction between IPA-proponents and reviewers including members of the public, is judged to be an important confidence-enhancing element. Also predictable interaction with decision makers and a staged decision process with logical steps are deemed important in this context. A clear record of past decisions and their basis and presenting qualitative arguments and calculations that support design choices and compare key options; are judged essential for motivating optimisation.

Compilation of answers

Several respondents discuss the benefits of review and a well-structured decision process. Posiva stresses the importance of clear and transparent regulations, interaction with reviewers and decision-makers and well-defined decision-making procedures. Posiva also notes that their stepwise process means that the safety and technical feasibility will still be tested at least twice before operation of the repository. Therefore, it is understood that full confidence in the approach is not yet needed. According to BfS the development of the safety case, the preparation of the technical reports, and the conduction of the review in parallel giving feedback on the degree of confidence in the developed statements, was considered a satisfactory procedure. GRS-K recognises the benefits of a stepwise and flexible approach to the safety case and the use of procedures to reach confidence in the feasibility and long-term safety of the project to all the stakeholders. UK Nirex Ltd used reviews both by technical contractors and by a technical writer to ensure accurate and clear arguments. OPG suggested that it is widely believed that confidence in the IPAs tends to increase substantially when there are more opportunities for the IPA-proponents to meet and interact with IPA-reviewers, including members of the public. GRS-B notes the benefits with the participation and competition of different companies. The authorities (SKI and SSI) conducted independent calculations, which they judged to be very important in the process of understanding the safety functions of the repository and to improve the overall confidence that the harmful effects of the repository are likely to be limited. BNFL notes that the publication of the UK regulatory guidance (the GRA) in 1997 has proved very important in setting the context for the 2002 Drigg PCSC (Post-Closure safety case).

Additional aspects listed by respondents include the following:

- cautious attitude towards uncertainties, withstanding the temptation to base conclusions on an evaluation of the performance measure using the most expected values of uncertain parameters (HSK);

- the fact that compliance with acceptance guidelines showed to be relatively insensitive to results of “what-if” scenarios (ENRESA);
- the elements of QA in safety calculations (ONDRAF/NIRAS);
- comparisons with other IPAs (JNC);
- presentation of arguments and calculations in a hierarchical, logical fashion (USDOE);
- the cross fertilisation of ideas among different disciplines involved in the IPA (USNRC); and
- participation in relevant international collaborative programmes, notably those co-ordinated by the NEA and IAEA (BNFL).

UKEA requires optimisation. The Agency will expect a developer to demonstrate optimisation by (1) providing a clear record of past decisions and their basis as considered at the time, and (2) presenting qualitative arguments and calculations that support their design choices and compare key options still open to the developer.

Several respondents (ANDRA, RAWRA, AECB, and SKB) did not provide additional aspects potentially contributing to overall confidence.

A3. DEMONSTRATING THE ADEQUACY OF BARRIERS AND MULTI-BARRIER SYSTEMS

A3.1 Definition of a barrier and the multi-barrier concept

A3.1.1 How do you define a barrier?

The International Atomic Energy Agency (IAEA) Radioactive Waste Management Glossary [IAEA, 1993] defines a barrier as follows:

"*A physical obstruction that prevents or delays the movement (e.g.: migration) of radionuclides or other material* between *components in a system, e.g. a waste repository. In general, a barrier can be an engineered barrier which is constructed or a natural barrier which is inherent to the environment of the repository.*"

A more recent draft IAEA Safety Glossary [IAEA, 1998] defines a barrier as follows:

"*In general, any physical obstruction that prevents or inhibits movement. In the context of radioactive waste disposal, a* physical *obstruction that prevents or delays the movement of radionuclides between components in a repository.*"

IPAG -3 participants were generally satisfied with the IAEA definitions of a barrier, and saw little benefit in trying to improve on the definitions. It should be noted, however, that some IPAG participants and NEA Member countries have definitions that vary from the IAEA definitions. In particular, some expand the definition of a barrier to include physical and chemical processes that inhibit or delay the release and migration of radionuclides. IPAG participants agreed that it was acceptable to us a variation of the IAEA definitions for a barrier in an Integrated Performance Assessment (IPA) as long as the definition was clearly stated and consistently used throughout the document.

Compilation of answers

Many respondents define a barrier as a physical component that contributes to the isolation of radionuclides from the surface environment and to the safety of the repository. According to ENRESA it is a feature (physical component) which prevents and/or limits and/or delays radionuclide migration from the waste or repository into surroundings. According to RAWRA barriers are components with safety functions. According to BfS, GRS-K, GRS-B it is a feature of the repository system that limits the migration of radionuclides and each barrier has one or more safety enhancing functions. GRS-B also notes that a safety function can also be a cause for a barrier effect, e.g. sorption in the geosphere, but in this case, it is said that the geosphere is the barrier and sorption is the barrier effect. UK Nirex Ltd uses the IAEA definition. AECB staff considers a barrier to be a physical component of the system, as opposed to a safety function (a physical obstacle that, by virtue of its attributes and properties, prevents delays or otherwise impedes the movement of contaminants, and thereby contributes to waste containment and isolation). According to HSK and Nagra, a barrier is a physical component or a defined property of a component of the system that results in confinement or retardation. A barrier may have more than one safety function and, conversely, a safety function may be provided by the operation of more than one barrier (Nagra). A barrier is defined as one of the physical component canister, buffer or rock (SKB). In proposed regulations (10 CFR Part 63), a barrier is defined as "any material or structure that prevents or substantially delays movement of water or radioactive materials" - a barrier is a physical component of the system (USNRC). To SKI it is a component of the system that limits the releases of radionuclides by chemical and/or physical phenomena and to UKEA it is a feature that delays or prevents migration of material within the disposal system (UKEA). The term barrier is generally used within the Drigg Post-Closure safety case to mean a physical component of the system rather than a safety function and BNFL usage is intended to conform to the UKEA guidance.

Some respondents are less clear and seem to include some "barrier effects" in the definition. According to ANDRA, a barrier is defined as one or several components with functions related to the containment of radioactivity in the geological-disposal concept. For each component described in a concept, the component is defined as a containment component, a design component or process containment. JNC notes that, in general, a barrier is a physical component of the system and a barrier could have more than one safety function. JNC does, however, refer to some safety functions related to radionuclide migration as "barriers". Posiva notes that the Government Decision (478/1999) on the safety of disposal of spent nuclear fuel defines that "barrier shall mean the host rock and a technical structure or material surrounding the disposed radioactive substances, as well as a physico-chemical interaction which hinders or slows down the release and migration of the disposed radioactive substances". For ONDRAF/NIRAS, a barrier is any component of the disposal system that contributes to the main safety functions of the system. Those safety functions are "physical confinement", "retardation / spread release", "dilution / dispersion" and "limited accessibility". According to OPG, a barrier in the previous safety assessments is a feature of the disposal system that contributes to safety, which means that also the consequence of a chemical or physical process that occurs at some unspecified location is considered a barrier. In future safety assessments, the definition of "barrier" may be limited to the physical components of the disposal system, consistent with the IAEA definition. USDOE notes that the TSPA-VA does not define the word barrier, but that other YMP documents define "barrier" as performing a function in maintaining waste isolation for a specified minimum time, or controlling release after isolation has failed to a certain maximum rate.

A3.1.2 Is the barrier definition stated in the IPA?

Most organisations state the barrier definition in the IPA. The motives for not stating the definition vary, but one reason is that the definitions are given in regulations. IPAs not providing the definition of a barrier still describe their safety functions.

Compilation of answers

Most organisations (ANDRA, ENRESA, JNC, ONDRAF/NIRAS, BfS (in glossary), OPG and SKB) state their barrier definition in the IPA. It is defined in the UKEA GRA glossary.

The motives for not stating the definition vary. Posiva notes that the definitions given in the regulations were not repeated in the TILA-99 report. AECB suggest that the AECL staff considered that a barrier was adequately defined in AECB Regulatory Documentation. According to USDOE the definition was not stated because it was not deemed essential to the purpose of the TSPA-VA. USNRC notes that the formal definition was formulated after the IPA for inclusion in regulations.

While the term “barrier” was not defined in some IPAs, the IPAs did describe the safety functions of the barriers. RAWRA notes that the barrier components and their safety functions are described. The UK Nirex Ltd IPA explains that the repository concept involves physical, chemical and geological barriers, which act to contain and delay the migration of radionuclides. GRS-B notes that the inner and outer barriers and their modes of action are described in detail. Nagra and HSK note that the individual barriers were listed, together with the safety functions that they are expected to provide, or contribute to, and it was felt that this provided a sufficient indication of what was meant by a barrier. SKI notes that a strict definition of what is meant by a barrier was not included, but the specific barriers included in the SFR as well as the general functions of different barriers were explained

A3.1.3 Definition of the multiple barrier concept

The IAEA Radioactive Waste Management Glossary [IAEA, 1993] defines multiple barriers as follows:

“*Two or more barriers used to prevent radionuclide migration from and isolate waste in a disposal system*.”

The draft IAEA Safety Glossary [IAEA, 1998] has a similar definition:

“*Two or more barriers* used *to isolate radioactive waste in, and prevent migration of radionuclides from, a* repository.”

IPAG-3 participants agree with this basic definition. In its simplest form, a multi-barrier system is a system with two or more barriers that meet the above-mentioned definitions for a “barrier”. Some IPAG-3 participants expand on this definition, and attach general performance objectives or requirements to a multi-barrier system. For example, most IPAG participants extend the definition to state that the barriers, taken together, should compensate for uncertainties and provide for a high degree of assurance for long-term safety. Many participants state *that the multiple barrier concept implies that safety should not be dependent on a single barrier*. It appears wise to clearly state the definition of the multiple barrier concept that is used in the IPA, and ensure that the term is used consistently throughout the document.

Compilation of answers

According to ONDRAF/NIRAS, the multi-barrier concept just means that there is more than one barrier in your system. UK Nirex Ltd gives a similar definition. RAWRA, OPG, AECB, BfS, GRS-B, and Nagra extend the definition and also include that the barriers, taken together, should provide a high assurance of safety. BfS, GRS-K and GRS-B note that the German “Safety Criteria for the Final Disposal of Radioactive Waste in a Mine” define the multiple-barrier concept, and that single barriers or a sum of different barriers must confirm, that in all probability no inadmissible release of radioactive substances into the biosphere occurs. Depending on the assumed “accident” (deficiency), the particular barrier contributes to the prevention or delay of the propagation of radioactive substances. AECB notes that sufficient redundancy in barrier functions (i.e. impediments to contaminant transport) is required to provide confidence or reasonable assurance that the long-term regulatory/safety criteria will be met. BNFL notes that in the context of the Drigg PCSC (Post-Closure safety case), the multi-barrier concept recognises that various barriers exist and that these barriers may act in isolation or have a cumulative effect. However, the Drigg PCSC is not founded on the multi-barrier concept because the repository is effectively located close to/in the biosphere. Instead, the safety case is founded on the low concentrations of radionuclides in LLW.

Several participants support the formulation that the multiple barrier concept also implies that the safety should not depend on a single barrier only (ANDRA, JNC, Posiva, HSK, SKI, SKB, USDOE, USNRC). Posiva notes that the Finnish regulations states the need for redundant barriers so that deficiency in one of the barriers or a predictable geological change does not jeopardise the long-term safety. According to USNRC, if a barrier does not perform as well as it is expected to, there should be another barrier that can take up the slack. Multiple barrier requirements do not mandate redundancy of barriers although it obviously does not prohibit it.

According to ENRESA, there should be a demand that barriers must be compatible between themselves and have different nature and mechanisms. JNC states that individual barriers have redundant safety functions to compensate for inevitable uncertainties in long-term performance. However, they are not totally independent, in that the disposal system consists of components that act together in a complementary way. HSK suggests it is implied that the barriers should be of different nature (in order to have low risk of common cause failures). Also SKI notes that a significant feature to preserve safety is that the barriers will respond differently to the various processes or events that may threaten the integrity of the repository.

UKEA does not use the multiple barrier concept, and prefers to refer to a “multiple – factor Safety case”.

A3.1.4 Definition stated in the IPA?

Those who do not state the definition refer to regulations or international documents or have assessments with less reliance on the multiple barrier principle. Retrospectively it is suggested that it may be useful to repeat the definition in the IPA even if it is given by regulation. (See also next section).

Compilation of answers

Most IPAs state their definition of the multiple barrier concept (ANDRA, ENRESA, JNC, ONDRAF/NIRAS, UK Nirex Ltd, GRS-K, OPG (effectively), and SKB).

Posiva did not repeat the regulations. BfS notes that the geosphere was the main barrier and therefore, the multi-barrier concept is not applied formally in the long-term safety assessment. GRS-B suggests that the application of the multi-barrier concept is included implicitly. AECB notes that the AECL staff considered that the multi-barrier concept was adequately defined in AECB Regulatory Documentation and other IAEA/NEA Documents. Nagra and HSK note that the definition used in the Swiss programme is given in the HSK/KSA regulatory guidelines, but in retrospect Nagra suggest it may have been useful to repeat the definition in the IPA. SKI notes that the multi-barrier concept was not used extensively in the IPA and the definition was therefore not included. USDOE notes that the emphasis in the VA was total system performance. USNRC refers to the discussion in regulations.

A3.1.5 Purpose and minimum requirements for a multi-barrier system

The purpose of the multi-barrier system is to provide confidence in the long-term safety, by providing a degree of redundancy to compensate for the uncertainties in the performance of individual barriers. Multiple barriers should also minimise the probability of “single-mode failure”.

No one requires redundant barriers or safety functions, but require sufficient overlap in safety functions to ensure overall safety. Most organisations also require that the loss of one substantial part of the barrier system should not lead to unacceptable consequences in terms of dose.

Compilation of answers

ENRESA states that the purpose of the multi-barrier system is to provide confidence in the long-term safety by compensating for the uncertainties in the performance of an individual barrier. JNC states that the purpose of a multi-barrier system is to provide multiple safety functions which are intended to compensate for uncertainties in the future behaviour of the individual barriers, especially future hydrological conditions. ONDRAF/NIRAS has installed additional near-field barriers (e.g. conditioned waste form, overpacks) to create a more redundant system. AECB states that sufficient redundancy in barrier functions (i.e. impediments to contaminant transport) is required to provide confidence or reasonable assurance that the long-term regulatory/safety criteria will be met. SKI notes that an important purpose of the multi-barrier system is to demonstrate that the repository system is robust. According to GRA requirements issued by UKEA, it should be shown that, even with an adverse interpretation of any given aspect of the evidence taken in isolation, the overall system performance would still provide acceptable assurance of safety and not display "cliff-edge" effects (i.e. sudden or rapid deterioration).

In Germany there is no specific requirement other than overall safety, redundancy is desired as a positive aspect (GRS-B). GRS-K refers to the answer under the previous section. According to UK Nirex Ltd there are no "minimum requirements", but regulatory requirements state that the safety of the disposal concept should not depend unduly on any single system component. Nagra notes that the multi-barrier concept (or, more precisely, the use of a series of passive barriers with multiple safety functions) is adopted to minimise the probability of "single-mode failure". In particular, the barriers are designed to ensure that there is an acceptably low probability that any event or process could significantly undermine the safety of the overall system. According to SKB, no effort is made to define a minimum requirement on redundancy. According to USDOE, no requirements are given on what barriers to use or how to show their efficacy. The Site Recommendation performance assessment analysis will have to show what barriers are important and how those barriers work together to reduce uncertainty. BNFL notes that possible performance indicators (e.g. barrier lifetimes) for various components of the multi-barrier system may be discussed in qualitative terms but there are no minimum requirements because the safety case is not primarily founded on the multi-barrier concept but on the disposal system as a whole.

Posiva and HSK state that the minimum redundancy requirement is that a deficiency in one of the barriers or a predictable geological change does not lead to unacceptable consequences in terms of dose. OPG believes that it is appropriate to require some degree of overlap in the functions of the barriers such that safety is not reliant on a single barrier. The degree of overlap should not be prescribed, but should be tested by examining the performance of the system in the event of unexpected, but credible, failure of each of the barriers separately (for example, by "what-if" analyses). USNRC states that the minimum requirement is to demonstrate that the repository does not depend on a single barrier for its performance and that there is a diversity of barriers, but redundancy is not required. ANDRA specifies requirements both for natural and engineered barriers according to the functional analysis. Function redundancy is thought for each of the different barriers.

A3.2 Evaluating the adequacy of a multi-barrier system

A3.2.1 Means of evaluation

There are essentially three approaches or techniques of exploring the adequacy of a multiple barrier system:

- to explore the evolution of barriers (including scenario and FEPs analyses) in order to find out if the safety functions will change over time;
- to evaluate the barrier effectiveness under a given scenario (using results of radionuclide release and transport calculations);
- to explore consequences of one or more barriers being less effective (or failed) without fully explaining why this situation could occur ("what-if").

Most IPAs use all these approaches. In fact, evaluating multiple barriers adequacy is almost equivalent to the whole IPA.

Compilation of answers

One means of evaluating the adequacy is to explore the evolution of barriers in order to assess their future performance. ANDRA performs qualitative analysis by listing different events or disturbances during the operational and post-closure phases, and by finding out solutions for limiting the occurrence of the event or disturbance and the consequences. JNC analyses natural-event scenarios leading to potential time-dependent changes in the properties of engineered and natural barriers. The way of identifying and structuring the different scenarios led ONDRAF/NIRAS to calculations of separate functioning of the different main barriers. ENRESA (and others) explores the physical nature of the barriers under different scenarios.

Another means of analysis is evaluation of the barrier effectiveness under a given scenario. UK Nirex Ltd describes the performance of each of the barriers separately and qualitatively, in terms of the radionuclides from the disposal inventory, which will be contained by that barrier. OPG notes that the EIS included a lengthy discussion on the "analysis of barrier effectiveness", in which a series of calculations were undertaken to describe how different barriers contributed to isolation and safety. The probabilistic analyses in the EIS and SCS can be regarded as a collection of scenarios in which the effectiveness of the barriers is varied. The Nagra IPA Reference Case is based on a set of "realistic-conservative" parameter values. SKB explores poor barrier functions by using pessimistic but not completely unrealistic data. The USDOE TSPA-VA analyses included sampling over ranges of parameters defining the extent of barrier function, and several sensitivity studies were done with and without a specific barrier or barrier-process to show potential importance. While the UKEA GRA does not specify scenarios to be evaluated, it does ask for assessments of radionuclide release characteristics from the waste and from various barriers constituting the disposal system.

In addition, most IPAs also explore consequences of one or more barriers being less effective (or failed) without fully explaining why this situation could occur ("what-if"). The ANDRA IPA includes assessment of a short-circuit of part of the geological barrier in the drift near the plug and a direct pathway for radionuclides released from the waste packages through the plug, followed by a direct and immediate transfer to the biosphere. ENRESA (and others) explores very early failure of the canisters. JNC evaluates cases in which a key barrier was less effective than expected. Most release and transport analyses of the radionuclides in TILA-99 (Posiva) deal with cases where one or several of the barriers are less effective than expected including a “disappearing” copper canister after 10 000 years. BfS notes that a number of safety enhancing functions of the repository system (e.g. limitation of release of radionuclides from the waste, transport processes in the repository) are neglected in the performance assessment due to their minor contribution to the overall safety. In the KONRAD performance assessments, different safety enhancing functions of the geosphere are taken into account (GRS-K). The investigation of barrier failure is done in terms of parameter variations (GSR-B). AECB notes that AECL assessed the impacts of a number of early roof failure scenarios. OPG notes that the EIS discussed the “effects of selected site and design features”, some of which correspond to special analyses where a barrier was made more or less effective. Nagra also considers “conservative” values taking into account situations where some unlikely detrimental process or event had reduced the effectiveness of a safety-relevant feature or process. Nagra also included a so-called 'robust case' where the transport resistance of the geosphere was hypothetically neglected. SKB dedicates a whole scenario to initially defective canisters and also explored lost barrier functions with unrealistic input data. USNRC suggests that barrier effectiveness may be quantified by assuming some barrier(s) underperform, and then assessing system performance. According to SKI, it is acknowledged that the long-term degradation of the concrete barrier is hard to predict and therefore conservative assumptions were made regarding its long-term physical resistance. No special cases with even more reduced barrier performance are considered, but SKI considers a case in their own dose calculations with a possible reduction of the Kd values due to the presence of complexing agents. The BNFL Status Report contains some illustrative calculations on the effect of barrier performance on assessment results

A3.2.2 Description of assumed barrier failures

Assumed barrier failures are usually modelled by making pessimistic assumptions about parameters and processes that result in reductions in the isolation or containment capabilities of the barrier. However, less often the consequences of a barrier not being present are evaluated. In particular, there are (almost) no analyses of a repository without a geosphere since this scenario would not be consistent with the concept of “geologic” disposal. It seems that the word failure is potentially misleading and might always be well defined if used in an IPA.

Compilation of answers

Table A-2 displays examples of assumed barrier failures analysed in the different IPAs. One should also note that some assessments do not define “failure”, but rather explore the isolating and retarding functions of the repository based on an assessment of the barrier evolution. The Table does not necessarily cover these aspects of “failures”.

Table A-2. **Examples of scenarios where barriers were assumed to be less effective than anticipated, or non-existant.**

Barrier	Scenario
Waste matrix	• All of the spent fuel is exposed as soon as the waste package fails - no credit is taken for the fuel cladding • Fast fuel degradation • Fraction of radionuclides released instantaneously is increased
Canister/ Container	• Initial defect (small hole) • Early failure (no retention for some canisters) • Massive failure (no retention for all canisters)
Buffer	• Conservative (i.e. low) retention values • Unlimited solubility • Reduced buffer thickness (due to degradation) • Buffer acts as a mixing tank with through flow
Seals	• Increased permeability
Geosphere	• The disposal vault is located nearer to or farther from a fracture zone. • Increased permeability • Short travel times • Very high flows • “By-pass” (i.e. total neglect of retention in geosphere) • A major post-glacial rock movement hits the repository at 30 000 years, breaks canisters, displaces bentonite, enhances flow and transport, and brings about oxidising conditions in the whole near field and geosphere • Total loss of geosphere barrier as a result of erosion or extensive human intrusion

A4. SUPPORTING ARGUMENTS

A4.1 Multiple lines of reasoning

Multiple lines of reasoning are a set of complementary arguments that use different approaches to evaluate and build confidence in long-term safety. Examples of approaches that can be used to develop multiple lines of reasoning include scoping and bounding calculations, natural analogues, paleohydrogeology and a variety of safety indicators. A line of reasoning does not have to address all aspects of safety, nor does it have to be fully independent from other lines of reasoning. Different arguments may be more appreciated by some audiences than other.

A4.1.1 Use in IPAs

Most respondents use multiple lines of reasoning in their IPAs (or multiple lines of reasoning were used in the IPA reviewed). The nature of the arguments varies significantly between IPAs as can be seen from the next section. Some respondents have not used multiple lines of reasoning, but rather concentrated on the main line of reasoning based on the detailed, rigorous performance assessment.

Compilation of answers

Most respondents (ANDRA, JNC, ONDRAF/NIRAS, Posiva, RAWRA, BNFL, UK Nirex Ltd, BfS, GRS-K, GRS-B, AECB, Nagra, and SKB) have used multiple lines of reasoning in their IPAs (or multiple lines of reasoning were used in the IPA reviewed). The nature of the arguments varies significantly between IPAs as can be seen from the next section. UKEA considers that a risk assessment or any other technical assessment is unlikely to be sufficient on its own to provide a satisfactory demonstration of safety. Sufficient assurance of safety over the very long time scales which may need to be considered is likely to be achieved only through multiple and complementary lines of reasoning.

Some respondents have not used multiple lines of reasoning. The only line of reasoning for demonstrating confidence in long-term safety used by ENRESA was just the scientific reasoning, describing the characteristics of the disposal system and quantifying the performance of the overall system in terms of radiological safety. In HSK's view, there is only one complete chain of reasoning for the safety of the repository system. There are supplementary arguments, however. The TSPA (Total System Performance Assessment) approach, by USDOE, did not explicitly call out and provide statements of multiple lines of reasoning; however, it did consider alternate approaches, processes, etc. Multiple lines of reasoning will be used in the Site Recommendation assessment. USNRC did not make a safety case, as this was not the object of the IPA. The USNRC recognises that multiple lines of reasoning are crucial for achieving 'reasonable assurance' about the safety. SKI did not find any examples of multiple lines of reasoning.

A4.1.2 Type of arguments used

The type of arguments used depends upon the context. Examples, used in the different IPAs include:

- the robust and achievable nature of the repository concept;
- the results of the IPA in terms of radiological safety, stemming from systematic IPAs, the extensive research programmes, site testing and experimental data;
- the exploration of the expected normal evolution of the system, thereby providing arguments for long term barrier functions;
- that there are reserves of performance in the safety case that could, if required, be mobilised;
- the assessment of consequences of assumed barrier failures/deficiencies, i.e. explorations of the redundancy in the multiple barrier system;
- the model verification and means to improve model transparency by using simple insight models in parallel with more complex assessment models;
- the paleohydrogeological arguments, such as study of the behaviour and migration of naturally occurring radionuclides or other relevant elements at the investigated site (see also Section A.4.2);
- the use of natural analogues (e.g. comparison with observations from uranium ore deposits and comparisons such as Cigar Lake and Oklo, see also Section A.4.2);
- the alternative safety indicators (e.g. ecological risk assessments, impacts of releases of non-radioactive contaminants on ground water quality, relating doses to levels of natural background radiation, see also Section A. 4.3);
- for LLW, a simple, but quantitative example included to provide a perspective on the hazard represented by the waste after 500 years;
- comparisons with other IPA studies and the developing international consensus on how to perform IPAs.

It should be obvious that the above list is not a recommendation of which arguments to make but just a short summary of different arguments used in different IPAs.

Compilation of answers

The nature of the repository concept is one line of reasoning. ANDRA stresses the need to show compatibility between materials, retrievability and cost. Nagra notes that large quantities of relatively well understood materials are used within the system of engineered barriers, to reduce the impact of potentially detrimental phenomena and facilitate quantitative evaluation of performance. BNFL stresses the need to describe the safety case context to clearly set out top-level assumptions and constraints and the reasons for these.

Regarding the IPA, the first line of reasoning is the scientific reasoning, describing the characteristics of the disposal system and quantifying the performance of the overall system in terms of radiological safety. The main arguments stem from the extensive research programme, site testing and observational elements with accompanying data sets. ANDRA, JNC, ONDRAF/NIRAS, RAWRA, Posiva, GRS-K, BNFL, AECB, OPG, Nagra, SKB, USDOE and USNRC, but is obviously valid for all note this argument.

Some assessments spend specific effort in exploring the expected normal evolution of the system and thereby providing arguments for long term barrier functions. Posiva and SKB use such arguments to show canister integrity for a very long time. GRS-B uses thermomechanical and geochemical calculations to prove the long-term behaviour of backfill. Studies of the geological environment indicate that it provides a favourable physical and chemical environment for the engineered barriers, ensuring their longevity (Nagra). GRS-K notes that the (qualitative) long term prediction of the geological situation of the KONRAD site shows a stable and robust site and barrier system.

Nagra notes that there are a number of features, events and processes that can contribute positively to repository performance, but are not represented in the assessment models. Thus, there are reserves of performance in the safety case that could, if required, be mobilised.

There are several examples of assessing consequences of assumed barrier failures/ deficiencies, i.e. explorations of the redundancy in the multiple barrier system. Posiva (and SKB) note that consequences are not significant even if several canisters were initially defective or failed for some reason at a later time. In the base case, ONDRAF/NIRAS assumes that the engineered barriers do not significantly contribute to the overall safety and as variant they explored what level of safety can be assured by a system only being composed of engineered barriers and a non-barrier surrounding. GRS-B demonstrated by dose calculations that the backfill keeps its effectiveness even if its permeability has not the specified value. One line of reasoning in the AECL EIS included a study of the contributions to safety from different barriers (OPG). Nagra presents a robust case demonstrating that even when highly pessimistic assumptions are made regarding specific aspects of the multi-barrier system, the overall system continues to provide an adequate level of calculated performance. USDOE notes that the margin of safety, defence-in-depth and consideration of potentially disruptive processes and events should be part of the safety case.

Model verification and means to improve model transparency by using simple insight models in parallel with more complex assessment models are other lines of reasoning. UK Nirex Ltd explains the behaviour of each of the barriers in respect of the key radionuclides in the disposal inventory, uses a simple, analytical "insight model" to represent this behaviour mathematically and then construct more complex computer models to perform more detailed calculations. BfS uses different hydrogeological conceptual models to support the results of the radionuclide transport calculations. AECB and Nagra note that scoping calculations with analytical solutions provide a simple, transparent verification. SKB also applies simplified approaches to showing safety using extreme cases in numerical modelling, analytical calculations and a simplified qualitative description of the nature of the models used in the transport calculations. USNRC notes the importance of model verification and use of alternative models.

Some IPAs use paleohydrogeological arguments. ONDRAF/NIRAS sought additional arguments in a study of the behaviour of naturally occurring K, U and Th in the Boom Clay. Studies of the chemical and isotopic composition of groundwater provide evidence that groundwater movement is extremely slow (Nagra). SKB uses paleohydrogeological arguments to some extent for understanding today's groundwater situations at the sites.

There are also some examples of the use of natural analogues. JNC and SKB note that they are discussed and USDOE and USNRC note that they should be discussed in IPAs connected to licensing. OPG notes that for covering longer time frames, the EIS included an analysis of trends from the quantitative evaluation of trends from the quantitative analyses, comparison with impacts from uranium ore deposits and comparison with observations from Cigar Lake and Oklo. Nagra notes that the overall concept of safe geological disposal is supported by evidence from natural analogues.

JNC (and others) has used alternative safety indicators. The IPA reviewed by AECB includes an ecological risk assessment. It also addressed impacts of releases of non-radioactive contaminants on ground water quality. In the SKB, IPA calculation results are related both to dose limit and level of natural background radiation (but not too naturally occurring releases). GRS-K uses the (low) groundwater velocity and groundwater ages as alternative safety indicators. BNFL tries to raise awareness of other sources of environmental radioactivity and to consider factors influencing the perception of risk.

In the IPA reviewed by AECB, there is a simple, but quantitative example included to provide a perspective to the danger represented by the waste. The predicted inventory of radionuclides in the vault at 500 years (the design life for the roof of the IRUS facility) was compared to the IAEA (1995) proposed clearance levels for removal of radioactive material from regulatory control.

Finally, comparisons with other IPA studies and the developing international consensus on how to perform IPAs have been used as arguments. Posiva specifically notes this point in this answer, but it would be probably true for many more.

UKEA does not specify how the developer should construct multiple lines of reasoning.

BNFL also notes the importance of demonstrating commitment to continuous improvement of the safety case with a forward programme targeted at key issues and also of demonstrating that impacts during the operational phase are in line with current regulations and are not radiologically significant.

A4.1.3 Overall conclusions and benefits from making the arguments

Generally, respondents suggest that the multiple lines of reasoning arguments supported their safety cases or the arguments for proceeding with R&D, siting etc. as intended. There may in fact be fewer criticisms made on qualitative arguments than on quantitative ones.

Compilation of answers

Generally, respondents suggest that the multiple lines of reasoning arguments supported their safety cases or the arguments for proceeding with R&D, siting etc as intended (ANDRA, ENRESA, JNC, Posiva, BNFL, UK Nirex Ltd, BfS, GRS-K, GRS-B, OPG, HSK, Nagra, SKB, USDOE). BNFL also notes that the benefit of using multiple and complementary lines of reasoning is that different needs for different audiences can be addressed within the framework of the complete safety case.

AECB notes that all arguments provided support for the case of long-term safety. The use of scoping calculations with analytical solutions provided a simple, transparent verification of the results of the more detailed assessments with the complex computer codes. This was effective, in that AECB staff did not have to review the complex computer codes in great detail.

OPG notes that the quantitative analyses in the EIS and SCS indicated that the disposal systems would meet the radiological risk criteria with a large margin of compliance, even when large ranges of uncertainty are taken into account. The subsidiary lines of reasoning suggested that the disposal systems were relatively robust. The longer-term qualitative arguments also concluded that the regulatory criteria would be satisfied. OPG notes that the mandate of some reviewers was to find deficiencies and other faults in the environmental impact statement, including the IPAs, and almost all comments are thus critical in nature. There were few negative comments concerning the reasoned arguments that cover the longer time frames. The implication is that most reviewers were generally satisfied with the content and extent of these qualitative lines of reasoning. The quantitative lines of reasoning drew numerous negative comments. Criticisms were directed at all elements of the detailed analyses: models, data and analytical methods. This may reflect the importance that the reviewers placed on the detailed analyses in the overall safety case.

A4.1.4 Arguments of potentially questionable value

Only a few respondents identified arguments with questionable or potentially detrimental value:

- natural analogues and multiple safety indicators could be difficult to apply in the IPA;
- complex quantitative analyses can impact on transparency and thus lead to significant criticism from reviewers;
- overly conservative values in order to show robustness may create a false impression of large uncertainties and may be difficult to change in future IPAs;
- detailed arguments often stimulate additional questions.

Most respondents have not identified any arguments of questionable or detrimental value.

Compilation of answers

JNC notes that parts of both the natural analogue and the multiple safety indicator assessments were less valuable in making the original IPA presentation. However, their long-term value in terms of public acceptance was difficult to quantify.

BNFL notes that formal feedback on the Status Report has not yet been received. This may reveal that some lines of reasoning are not contributing to the overall safety case and we must listen carefully to our stakeholders to ensure a well-focussed Post-Closure safety case is produced for September 2002.

OPG notes that the complex quantitative analyses and accompanying arguments had a detrimental impact on many reviewers of the EIS and SCS. In particular, the complexity and lack of transparency of the probabilistic safety assessment methodology using SYVAC may have been viewed as detrimental to the safety case.

Nagra notes a potential problem in using overly conservative hypothetical values, in that they may be misunderstood as a worst but still possible case, thus giving a false impression of limited system performance or existing uncertainties.

USDOE notes that all arguments were useful. However, specialists on external oversight and peer review panels felt that there were many unanswered questions. They asked pointed questions about sensitivities, which showed that they believed that only a few of the data sets were meaningful and important, and others were not important within the ranges of the data obtained. This was not to discourage the approach, however, but to suggest more of it should be done to really test the model and understand its limitations.

Most respondents did not identify any less useful arguments.

A4.2 Natural analogues and/or paleohydrology

A4.2.1 Were natural analogues or paleohydrology arguments used?

Most organisations use natural analogue or paleohydrology arguments in their IPAs. A few do not, mainly because they are in the concept development stage of their repository programme. However, USNRC suggests that there are too many uncertainties in paleohydrology and natural analogue data, and that their use adds only weakly to confidence statements.

Compilation of answers

Most organisations use natural analogue or paleohydrology arguments in their IPAs. A few do not. ENRESA did not use them due to the early stage of ENRESA's programme and due to the lack of concrete sites in the programme. RAWRA considers involving natural analogue arguments in the next revision of their study. GRS-B only used them to support arguments. USNRC only used paleohydrology to put an upper bound on water table rise, and natural analogue data was only used to constrain solubilities. In addition, they state that there are too many uncertainties in paleohydrology and natural analogue data, and that their use adds only weakly to confidence statements. SKI notes that the most relevant natural analogue that could have been used for the SFR, the Maqarin study, was not finalised when the safety report was written.

A4.2.2 Type of arguments and analyses

There are essentially three types of uses of analogue information. These are system wide arguments for overall performance, support for model or model components and demonstrating understanding in the migration of the studied site (paleohydrogeology).

One type of use of natural analogues concerns system wide arguments for overall performance. Natural analogue observations from Cigar Lake and Oklo are used to support the contention that uranium dioxide and many of its fission products could be effectively immobilised for billions of years in certain geochemical environments. Ancient burial tombs in China and Japan have been used as archeological analogues for the long-term performance of multi-layered, engineered roof structures.

The main use of analogue information concern support for models, model components or data. For instance, natural analogue studies provide support for:

- the long-term corrosion predictions of copper containers;
- the long-term stability of the bentonite buffer by the observation of little or no mineralogical change in montmorillonite-rich sediments;
- the slow corrosion of steel canisters supported by evidence from archaeological observations;
- the stability and resistance to corrosion of the glass waste matrix supported by the observation of longevity and low corrosion rates of natural basalt and old anthropogenic glasses;
- the low solubility/immobility of key elements supported by measurements of rock minerals and adjacent groundwaters;

- the degradation potential of cellulosic materials supported by investigations of ancient burial grounds and modern landfills.

Finally, there is an increased interest in trying to understand and model the past geochemical and hydrogeological evolution at the proposed repository site. The isotope signature of the water can be indicative of its isolation time since its meteoric input. The migration behaviour of Th and U in natural clay can become a very strong argument to show that migration of actinides in such clay can be extremely slow. However, some respondents do not see the need to specifically use the term paleohydrology. They see it as an intrinsic part of site characterisation and groundwater modelling. In addition there are other historical evolutions of the site, like tectonics, which also may be important to understand.

Compilation of answers

One use of natural analogues concerns system wide arguments for overall performance. Natural analogue observations from Cigar Lake and Oklo were used to support the contention that uranium dioxide and many of its fission products could be effectively immobilised for billions of years in certain geochemical environments. The connection was then made that the expected long-term chemical environment inside a disposal vault and surrounding geosphere closely parallels these geochemical environments (OPG). Nagra used the observed immobility of many relevant radionuclides as qualitative support for the overall concept of safe geological disposal. According to AECB, AECL used Ancient burial tombs in China and Japan as archeological analogues for the long-term performance of multi-layered, engineered roof structures. According to UKEA natural analogues may be especially useful in providing evidence or support for the longevity or reliability of components or materials under repository conditions. According to BNFL natural radioactive analogues are mainly used to set the results of the radiological safety assessment into context.

The main use of analogue information concerns support for models, model components or data. For instance, natural analogue studies provide support for the long-term corrosion predictions of copper containers (OPG). The long-term stability of the bentonite buffer is supported by the observation of little or no mineralogical change in montmorillonite-rich sediments (Nagra, JNC). The slow corrosion of the canisters is supported by evidence from archaeological observations showing that, in the absence of oxygen, steel/iron corrosion proceeds at very slow rates (Nagra, JNC). The observation of longevity and low corrosion rates of natural basalt and old anthropogenic glasses support the stability and resistance to corrosion of the glass waste matrix (Nagra, JNC). The low solubility/immobility of key elements e.g. of uranium and thorium are supported by measurements of rock minerals and adjacent ground waters (Nagra, JNC). The TILA-99 safety assessment includes references to natural analogues in association with corrosion of copper, fuel dissolution, matrix diffusion, and intrusion of oxygenated glacial meltwater (Posiva). According to AECB, AECL used information obtained from archeological investigations of ancient burial grounds and modern landfills in assessing the degradation potential of the cellulosic materials in the waste streams proposed for the IRUS Disposal Facility. USNRC used natural analogue data to constrain solubilities. UK Nirex Ltd used analogue data from both specifically designed studies and the general knowledge base of the geoscience community to I) check the appropriateness of parameters, ii) to aid the development of conceptual models, iii) test the completeness of FEP catalogues etc. BNFL used information from suitable analogues in the development and testing of models and computer codes. Consideration is also being given to using analogues to supporting engineering assumptions.

There are also several examples of the use of paleohydrogeological evidence of migration. HSK notes that the isotope signature of the water can be indicative of its isolation time since its meteoric input. Similarly, Nagra notes that paleohydrology provided support for the rate of movement and origin of groundwater. ONDRAF/NIRAS notes that the Boom Clay itself is a natural analogue, especially for the migration behaviour of Th and U, and thinks that this can become a very strong argument to show that migration of actinides in such clay can be extremely slow. USDOE notes that paleohydrology has had a major role in developing groundwater parameters for the TSPA-VA and that groundwater chemistry is very important for constraining unsaturated zone fluxes and velocities. GRS-B used some in-situ measurements on the mobility of radionuclides in the groundwater at Morsleben, in support of the laboratory data on sorption. BfS notes that observations on the age and salt concentration of the natural deep groundwater indicates groundwater movements of less than about 1 cm in 1 000 years or even stagnating groundwater and use this as a proof of a conservative groundwater model with respect to groundwater travel time and dilution. GRS-K notes that observation of nature and site-specific safety indicators have been extensively used for confidence building in performance and safety assessment. Posiva used paleohydrological evidence and natural analogues in the geochemical and overall site evaluations and in the normal evolution study. SKI notes that one piece of information related to paleohydrology that was mentioned in the safety report is that the groundwater near the repository is more saline than the Baltic Sea water.

A4.2.3 Added value of natural analogues

The added value of natural analogues is that they can be used in reasoned arguments (e.g. to demonstrate that containment occurs in nature), and they can give an indication of the fundamental, transferable understanding of those phenomena over the long term. They are important tools to derive confidence in experimental data and models for radionuclide transport. Generally, they provide confidence in qualitative aspects of the operation of features and processes over timescales that are unattainable in experiments, and provide evidence for the completeness of the processes considered in the assessment. Natural analogues, e.g. background radiation, also facilitates in putting the results of the radiological safety assessment in an appropriate context.

There are, however, some more reserved views. Their use as a data source is questioned. Also when applying natural analogues, the paleohydrogeology of both the disposal facility site and the analogue site must be known in sufficient detail to indicate that the analogue conditions and arguments are applicable to the facility site. One respondent suggests that although success in reproducing findings from natural analogue studies contributes to confidence in modelling methods, it is not generally possible to build unambiguous arguments in favour of the quality of models and data.

Use of paleohydrological information from the repository site generally enhances the understanding of the site and the credibility of the transport modelling and projections of the future development of the site. Studies of natural tracers can be used to constrain migration model data, but it is also noted that the past residence time of groundwater does not give any direct indication of the groundwater transit time from the repository to the biosphere.

Compilation of answers

OPG and AECB note that in the broadest sense, natural analogues of the disposal system as a whole and of various aspects of the disposal system (e.g. containment via geochemical barriers) can be used in reasoned arguments (e.g. to demonstrate that containment occurs in nature). Other analogues can be used to investigate specific processes and mechanisms, and be used to demonstrate a fundamental, transferable understanding of those phenomena. AECB notes that when applying natural analogues, the paleohydrogeology of both the disposal facility site and the analogue site must be known in sufficient detail to demonstrate that the analogue conditions and arguments are applicable to the facility site. UK Nirex Ltd has similar views. According to GRS-B, analogues are important tools to derive confidence in experimental data and models for radionuclide transport. BfS notes they were of utmost value in the licensing procedure to give reasonable assurance that the performance assessment, which was based on observations from nature, does not lead to erroneous results. Posiva notes that analogues are essential for understanding. USDOE notes that the natural analogue discussions were particularly helpful in showing that there was much thought given to the topic, and that there is a great awareness of the potential for analogues to help the safety case. According to Nagra, it provides confidence in (qualitative aspects of) the operation of features and processes over timescales that are unattainable in experiments, and provide evidence for the completeness of the processes considered in the assessment. According to SKI, natural analogues and/or paleohydrology can be regarded as the most important, if not the only way to claim that the long-term evolution of a natural system is reasonably well understood. Most people involved in safety assessment probably use natural analogues for confidence building even if they are not explicitly included in the final product. According to GRS-K, natural observations of the site itself are valuable for the confidence building process for the long-term aspects of assessing safety. According to BNFL, the results of the radiological safety assessment must be presented in an appropriate context to facilitate a decision-making process and information of natural analogues is a relevant aspect of this context setting.

Some respondents take a bit more reserved view. To JNC it is difficult to assess the “value” of the analogue studies other than to say that conceptualising a repository system is the most difficult task. Analogues play a critical role in evaluating concepts of processes and materials that are evaluated as part of the natural FEPs or the engineering design. Information obtained from natural analogue studies will probably be used to a minor degree by ANDRA to support the conceptual models proposed for representing certain phenomena considered in building the safety case. Posiva finds analogues less useful as a source of quantitative data and notes that the past residence time of groundwater does not give any direct indication of the groundwater transit time from the repository to the biosphere. Finally, HSK agrees that the apparent overestimation of transport speed by geosphere transport models is indeed a sign of conservatism of the transport modelling, but in order to turn that sign into increased confidence, the reason for the overestimate needs to be more quantitatively explained. Although success in reproducing findings from natural analogue studies do contribute to confidence in modelling methods, it is often not clear how to use the information obtained there to build unambiguous arguments in favour of the quality of models and data as used in the safety analysis of a repository. BNFL notes that some stakeholders will not be convinced by computer simulations matching analogue data because it is likely that analogue data will cover a time period of a few decades at most, whereas safety assessment calculations cover timescales of orders of magnitude longer.

USDOE suggests that without the paleohydrology and associated chemistry data, the unsaturated zone flow model would not be as well constrained as it is. AECB notes that confidence in understanding can be enhanced by knowledge of the site paleohydrogeology. Posiva states that paleohydrology is essential for understanding the past evolution of the candidate sites and in evaluating and explaining the future evolution of the disposal system. ONDRAF/NIRAS believes paleohydrology can significantly contribute to building confidence in the long-term behaviour of the main geological components of the repository system. ANDRA will certainly use the results of natural-tracer studies at their sites to support the parameters used to represent the transport processes responsible for radionuclide transport through the host formation and for the long-term average groundwater rate. JNC, on the other hand, states that the use depends on the concept and for their current generic IPA, with reliance on only a small portion of far-field rock, paleohydrological studies were of limited value.

A4.3 Additional indicators

Most organisations use additional indicators as a complement to risk or individual dose. A few have not, usually because their programmes are at a generic stage or by requirements from regulations.

There is quite a wide selection of indicators being assessed. Examples of indicators, in addition to dose rate to humans and individual risk, which have been assessed in different IPAs or reviews, include:

- comparing dose rate with the background;
- collective dose;
- radionuclide flux from various barriers compared with nuclide specific limits or the volume of natural environment with the same amount of activity, or as an illustration of the relative effectiveness in attenuating the releases of different radionuclides;
- calculated concentrations at selected points and compared with naturally occurring levels or toxicity;
- chemical toxicity impacts were assessed by comparing estimated concentrations in the biosphere with natural occurring concentrations and with the environmental increment;
- dose rates to biota or detailed ecological risk assessments for specific non-human biota at the site;
- time scales of engineered barrier isolation, i.e. groundwater travel times and the functioning over time of the different barriers;
- the spatial distribution of radiotoxicity between barrier components as a function of time, and also a comparison with the IAEA (1995) proposed clearance levels for removal of low-level radioactive material from regulatory control.

No respondent noted any conflicting evidence between the different indicators regarding safety.

Compilation of answers

Most organisations use additional safety indicators as a complement to risk or individual dose. A few have not. ANDRA considered radionuclides flux as alternatives since the purpose of the first step of the project development was limited to the selection of different concept options. It was out of scope for RAWRA. UK Nirex Ltd did not apply them in their generic assessment but plan to include them in the next iteration. USDOE notes that in the future, depending on the outcome of work underway to develop new regulations specific to a Yucca Mountain repository, other performance measures such as concentrations in, or doses from, groundwater may also need to be addressed. USNRC notes that other indicators were assessed but not as alternatives, but in addition to. According to UKEA since there is no objective method of assigning value to radionuclide fluxes or similar surrogate measures, there seems little value in adopting such measures to support optimisation. Rather it is preferable to use dose or radiological risk estimates. This does not rule out the use of complementary safety indicators in more qualitative illustrations of safety.

BNFL, UK Nirex Ltd, OPG (through the past AECL studies), SKB and ENRESA have all calculated individual risk. JNC did it for human intrusion as low probability event. Almost all calculate individual dose rate (ANDRA, ENRESA, JNC, Posiva, BNFL, OPG, Nagra, SKB, USDOE, and USNRC). SKB compared the calculated dose rate with the background as well as with the regulatory risk limits. SKI compared calculated dose rates with radon from wells to illustrate the risk associated with the least favourable (and bounding) calculation cases. Collective doses were also estimated.

ANDRA, JNC, Posiva, ENRESA, ONDRAF/NIRAS, OPG, BNFL and Nagra assessed the radionuclide flux from various barriers. Some used results to compare between concepts. In Finland, there are regulatory, nuclide specific limits on the long-term release from the geosphere (Posiva). Nagra assessed the ratio of flux maxima out of the geosphere to that into the geosphere, for individual radionuclides to illustrate aspects of the behaviour of the model of the geosphere transport barrier, such as its response to parameter variations and its relative effectiveness in attenuating the releases of different radionuclides. SKB also did this. ONDRAF/NIRAS compared the radionuclide flux with the volume of natural environment with same amount of activity, but also with fractions of inventory reaching the geosphere. USNRC used intermediate results such as ground water travel time, release rates from the unsaturated and saturated zone, waste package life time etc. to interpret results as well as to assure that the complex code was performing the calculations correctly (but not as safety indicators). SKI notes that the maximum release rates and the release rates as a function of time were presented individually for the different repository parts and for the different radionuclides. BNFL notes that the radionuclide flux and concentration results are used to explain the results in more detail. For example, a change in the flux of a radionuclide from the near field may be related to geochemical processes ongoing in the waste.

JNC, BNFL and Nagra calculated concentration at selected points and compared them with naturally occurring levels. Nagra calculated a normalised release rate from the geosphere (in mol/litre). OPG notes that comparing assessed chemical toxicity impacts estimated concentrations in the biosphere with natural occurring concentrations and with the environmental increment. AECB notes that AECL compared calculated concentrations of non-radioactive contaminants in ground water with water quality objectives and guidelines, and the baseline ground water concentrations for those contaminants at the site.

There have been attempts of calculating dose rates to biota (OPG). AECB notes that AECL compared calculated doses to generic, non-human biota with the criterion of 400 mGy/a, which the IAEA has proposed as a dose below which plant or animal populations will not be harmed (IAEA, 1992). In addition they performed a detailed ecological risk assessment for specific non-human biota at the site. Calculated doses and impacts from radioactive and non-radioactive contaminants to this non-human biota were compared to derived “expected no-effects values”.

The functioning over time of the different barriers are used as other safety indicators. By presenting the normal evolution scenario, Posiva assessed that the engineered barriers effectively hinder the release of radionuclides from the repository into the geosphere for several thousands of years. BfS and GRS-K calculated the groundwater travel time. BfS and GRS-K also assessed the time scale of processes by comparing with the age of salt concentration of the deep ground water. Nagra described the fate of the radionuclides, i.e. where in the repository or on the migration path they disintegrate and the time evolution of the concentration of selected radionuclides in different parts of the repository system. The distribution of overall radiotoxicity between components as a function of time, were also evaluated subsequently. ONDRAF/NIRAS presented the fractions of inventory reaching the geosphere. GRS-B and BfS used the temporal evolution of radiotoxicity to assess the impact of the total inventory of the repository. AECB notes that AECL compared the predicted inventory of radionuclides in the vault to the IAEA proposed clearance levels for removal of radioactive material from regulatory control (IAEA, 1995). SKI notes that an additional performance indicator could have been the long-term stability of the different barriers.

No respondent noted any conflicting evidence between the different indicators regarding safety.

A4.4 Biosphere considerations

A4.4.1 Representation and its adequacy

No assessment considered changes in human habits, although some considered the impact of climatic change or disruptive events on biosphere conditions. Long term human behaviour and biosphere conditions cannot be known with any uncertainty in the future, and thus stylised approaches are generally used for selecting critical groups and biospheres. Uncertainty in the biosphere is taken into account through conservative assumptions and by assessing the impacts of parameter uncertainty with probabilistic methods. Some make this analysis in the framework of the BIOMASS programme aimed at developing the "reference-biosphere" methodology [IAEA, 1999].

It is usually considered that the calculated dose rate is a "measuring instrument" for evaluating indicators of potential long-term radiological impact, and not a true prediction. The uncertainties are largely unavoidable, and are not amenable to R&D.

Some assessments did not consider any changes with time, but still considered site specific hydrogeological input. A simple reason could be a limited duration of the assessment period, but also long-term assessments may select not to explore any time rate of change, referring to the true difficulties in predicting such changes. Some took an even more generic approach. However, many reviewers have considered approaches with generic, non-site specific, well dilution factors to be insufficient.

Compilation of answers

OPG notes that in the past assessments the biosphere was an integrated component of the safety assessment model for disposal. Uncertainty in the biosphere was taken into account in probabilistic analyses, using probability density functions to describe feasible values of uncertain input parameters. Human habits are not judged to change, climate evolution is taken into account. Other parameters were assessed conservatively.

The biosphere in the USDOE TSPA-VA was based on the assumption that future human behaviour would be similar to current behaviour and predicting any changes would add more uncertainty to the analysis. Site specific information has been used for constructing the biosphere model. Additional models for disruptive events that might alter the current biosphere are also being developed. SKB developed a number of possible ecosystem types and adopted these to each site. In the IPA, reasonable and pessimistic dose conversion factors were chosen from the calculated pdf's and used to formulate reasonable and pessimistic calculation cases. According to SKI, it was acknowledged that uncertainties are introduced for the different time periods (seawater and inland) and the authors of the safety report stated that their ambition was to account for these uncertainties by selecting parameter values for the calculations in a cautious way.

According to the HSK regulatory guideline, dose estimates for the far future are not considered to be projections of dose for a real future population, but rather as a translation of releases from the geosphere into a measure that can be compared with regulations as well as with other community risks. Still, different climate scenarios are considered and the biosphere transport is modelled in such a manner that the importance of different pathways to man can be appreciated.

Where possible, parameters are chosen conservatively. To Nagra biosphere modelling is viewed as a procedure for the conversion of the calculated releases from the near- and far-fields to a common scale (annual individual dose). Especially for times far in the future the parameter it is not a prediction but rather an indicator of repository performance. Uncertainties are viewed as largely unavoidable, and not amenable to R&D.

ANDRA is working in the framework of the BIOMASS programme at developing the "reference-biosphere" methodology. Concerning the climate-change simulation, ANDRA will work in a few months with the European BIOCLIM project. JNC applied an approach for identifying and justifying a "reference biosphere" acting as a "measuring instrument" for evaluating indicators of potential long-term radiological impact. This approach was consistent with the Reference Biosphere methodology developed in BIOMOVS II, and is currently enhanced under the BIOMASS programme. According to BNFL, the adequacy of the representation of the biosphere is justified by reference to national and international best practice.

Some assessments did not consider any changes with time. AECB notes that given the hazardous lifetimes of the waste streams planned for the IRUS Facility, AECL assumed that the basic environmental conditions were unchanged from current day conditions over the duration of the assessment period. AECL made use of the extensive site-specific information. To account for the uncertainty regarding the nature and location of future human habitation, several conservative, yet reasonable, critical group scenarios were evaluated in dose calculations. AECL staff interviewed people that had lived in the area during the Depression years (1930s) to better understand the conditions and practices representative of "near subsistence lifestyles" in the vicinity of the site. The dose calculations in the USNRC IPA are based on a pre-defined (in the regulations) critical group and the expected maximum annual dose is calculated for an average member of this critical group. The only factor related to the biosphere that was considered to be uncertain in the TPA analysis was the pumping rate for water use. Site-specific data is used to define the life style of the critical group. ENRESA considers a constant biosphere with a self-supporting farm based on today's conditions and did not take climatic change into account. Conservative values were chosen for the transfer parameters through the food chain. ONDRAF/NIRAS calculated biosphere conversion factors, which are applied to the whole considered time period. UK Nirex Ltd derived flux-to-dose conversion factors, which are based on conservative assumptions, for example regarding consumption habits and occupation of contaminated areas. According to UKEA, the focus should be on identification of potentially exposed groups, and to deal with future human behaviour the developer should present assessments in terms of the impact on potentially exposed groups based on observed past and present human behaviour, justifying the particular groups chosen.

Some took a very simplified generic approach. Posiva considered a simple, non-site specific, drinking water well. This approach was, however, considered insufficient by many reviewers and a more detailed biosphere analysis is required in future assessments. In an assessment period that is adequately predictable (until about 10 000 years) compliance shall be demonstrated by assuming such a self-sustaining community in the vicinity of the disposal site that receives the highest radiation exposure. BfS, GRS-K, and GRS-B note that concentration to dose conversation factors are calculated according to the calculation rules laid down in an appendix to the German Radiation Protection Ordinance. RAWRA did not consider any biosphere analysis.

A4.4.2 Is the biosphere a barrier?

No one considers the biosphere to be a barrier but many see it as providing safety functions. Still many note the importance of dilution and dispersal in keeping low doses in assessment results.

Compilation of answers

ANDRA, JNC, ONDRAF/NIRAS, Posiva, RAWRA, UKEA, UK Nirex Ltd, BfS, GRS-K, GRS-B and OPG directly state that the biosphere is generally not regarded to be a barrier nor to provide safety functions. One reason for disregarding safety-related effects for the biosphere is because the biosphere can change relatively quickly compared with geologic time scales, and it would not be feasible to take credit for specific effects in the far future.

ENRESA notes that dilution in the aquifer has a strong effect on doses and plays an important safety function if dose or risk is used to quantify the isolation capability of a repository. JNC notes that the dilution and dispersion are nevertheless an important factor which affect radionuclide migration in the biosphere and hence the consequence of a release from the repository. AECB notes that dilution and sorption occur in the biosphere, and these processes tend to reduce calculated doses to the critical group. HSK notes that the safety functions related to the dispersal in the biosphere are important. Nagra notes that the biosphere has a significant effect on calculated doses in that surface and near-surface water provides considerable dilution, but notes that also accumulation processes need to be considered. SKB notes that dilution is (nevertheless) an important factor. SKI notes that the biosphere is not included as a barrier, but the dilution of radionuclides in parts of the biosphere can be considered as a safety enhancing function. USDOE notes that discarding the biosphere as a barrier does not mean that the modelling is not important, since assumptions about the pathways and dose conversion factors are important to the dose calculation. USNRC suggest the biosphere is a barrier only in the sense that the location of the critical group was based on depth to water table and the life style was accordingly specified, but did not include any credit for treatment or interdiction of radioactively contaminated groundwater. BNFL notes that in general the biosphere is considered to have safety functions and is not usually referred to as a “barrier”. Dilution reduces radionuclide concentrations, which directly reduces estimated doses to potential exposure groups. Attenuation by sorption increases the estimated time before potential exposure occurs, which may significantly reduce the impact for short-lived radionuclides.

A5. DEMONSTRATING THE ROBUSTNESS OF THE SYSTEM OR COMPONENTS OF THE SYSTEM

The questions and answers compiled in this chapter concern to what extent the concept of robust repository systems or robust components of the system is or will be used in IPAs and if the concept is found useful. (It should be noted that the questions and answers do not concern “robust analyses”).

A5.1 Specific examples of robustness

Examples given of robustness of the disposal system or parts thereof include:

- selection of concepts which are simple and easy to evaluate (diffusion in clay, waste containment during the thermal phase, oxygen free groundwater greatly simplifies the analyses of the chemical evolution of the repository, layout of deposition in order to avoid boiling water, the use of a carbon steel canister for which corrosion is determined by well-understood processes, durable copper-iron canisters, use of a bentonite buffer to diminish disturbances due to rock movements);
- selection of very stable geological formations with suitable and stable geochemical and mechanical environment enhance the confidence in the repository stability and keeps the repository away from the external influences,
- selection of sites which do not have resources of exceptional value making it unattractive to human intrusion,
- keeping technical measures as simple as possible : selecting drilling methods to reduce the disturbed zone, selecting the separation between canisters to guarantee moderate temperatures, using backfill materials with known characteristics, selecting ceramic canister materials to avoid iron corrosion gas, selecting a copper container of sufficient thickness to avoid sensitivity to kinetic uncertainties and pitting corrosion, selecting a low-permeability buffer which effectively de-couples the release performance of the EBS from the inherent uncertainties in future hydrological flow conditions,
- measures taken to add to or improve the safety functions: backfilling and sealing access routes to guard against future human intrusion, separation of waste into disposal canisters and disposal modules limits the effect of a single canister or module performing poorly, over-designing container and buffer durability, the possibility to adapt the repository to local rock quality by selecting the positions of the individual deposition holes etc.

In contrast, some respondents point out that their disposal concept builds on elements with fairly complex, but safety enhancing, processes. For instance, the presence of cement in the repository provides a “chemical barrier”, but it does increase the assessment modelling complexity due to the creation of an alkaline disturbed zone. In discussing robustness, the NEA document on Confidence in the Long-term Safety of Deep Geological Repositories [NEA, 1999] separates between *intrinsic* and *engineered* robustness. According to the document *engineered robustness* concerns "Intentional design provisions that improve performance with respect to safety, in order either to compensate for known phenomena and uncertainties or to guard against the possible consequences of undetermined phenomena". *Intrinsic robustness* is defined as "Intentional siting and design provisions that avoid detrimental phenomena and the sources of uncertainty through the incorporation of features that are simple, for which there is practical experience, and which are acted upon by processes that are well understood". However, the examples given for engineered and intrinsic robustness by IPAG-3 participants are not really different in nature. It appears to be less useful to uphold these two concepts, and better to simply discuss the aspects of system robustness collectively.

Compilation of answers

Simple and easy to evaluate designs and sites is one example of robustness. ENRESA notes that the use of a very simple architecture of the designs allowed simple performance assessment model-chains. ONDRAF/NIRAS points out that placing the repository in the Boom Clay simplifies migration modelling since diffusion is the main radionuclide transport mechanism. Also there is no need for thermal transport models since the waste overpack makes sure that no radionuclide migration and dispersion can take place during the hot phase of the repository. SKB notes that the requirement of oxygen free groundwater at the repository site greatly simplifies the analyses of the chemical evolution of the repository. Also the layout of deposition in order to avoid boiling water on the copper canister's outer surface allows simplification of the subsequent corrosion analyses of the canister. The use of a carbon steel canister for which corrosion is determined by well-understood processes could help to develop a robust corrosion model (ENRESA, Nagra). ONDRAF/NIRAS uses similar arguments to support the choice of stainless steel as a canister material. Posiva notes the durable copper-iron canisters will preserve their integrity for a very long time. Nagra notes that the use of a bentonite buffer provides robustness with respect to disturbances due to rock movements. According to BNFL, the most obvious example of intrinsic robustness is that the Drigg site only accepts low level, mostly short lived, waste for disposal, which limits the maximum possible impact compared to more highly active wastes. During this time engineering measures and institutional control for final site closure should remain largely intact.

Another cited example of intrinsic robustness is that the site is selected to be unattractive to human intrusion. For example, the site selected in Eastern France has no resources of exceptional value and the choice of man-made materials has been examined according to that criterion (ANDRA). The UK Nirex Ltd IPA explains the benefits of siting a repository at depth in a rock of low economic potential to minimise the probability of inadvertent future intrusion into the repository. HSK notes that there has been no site selection yet, but it is intended to avoid locations where exploitable resources reside in order to avoid the risk of human intrusion. Similarly, Nagra notes that the siting of the repository in a region with few economically viable natural resources underground provides robustness with respect to inadvertent human intrusion.

Several respondents (ENRESA, JNC, Posiva, RAWRA, BfS, GRS-K, GRS-B, OPG, Nagra, and SKB) note that the choice of a stable geological formation with a suitable and stable geochemical and mechanical environment enhanced the confidence in the repository stability. Positioning the repositories in regional recharge areas at sufficient depths gave long travel times for the groundwater and kept the repository away from external influences (ENRESA, RAWRA, BfS, GRS-K and OPG). SKB notes that the stable conditions at depth provide robustness with respect to surface environmental processes. GRS-B notes that the creeping behaviour of the rock salt causes a slow closure of the open voids in the near field, which finally leads to a safe en-closure of the disposed waste. SKI notes that for the first time period during which the repository is located below the Baltic Sea, dilution of radionuclides in the enormous seawater volume can be considered as an example of intrinsic robustness.

In contrast, some respondents point out that their disposal concept builds on elements with fairly complex, but safety enhancing, processes. The cement in the generic UK Nirex Ltd Reference Vault Backfill (NRVB) is an important part of the repository concept, providing the "chemical barrier"; however its use does increase the assessment modelling complexity due to the creation of an alkaline disturbed zone. USDOE points out that the Yucca Mountain site was originally selected based on arguments for the intrinsic robustness of a thick unsaturated zone, but the results of subsequent investigations have substantiated early assumptions about the probability of fast flow paths in the unsaturated zone. Flow and seepage mechanisms are not clearly understood, but multiple lines of evidence provide strong constraints on the magnitude of seepage through the repository horizon. USNRC notes that the location of the repository in an unsaturated zone with low seepage rates is intrinsically good, but the flip side of the same is the oxidising environment of the site, which is intrinsically not so good.

AECB notes that the proposed IRUS Disposal Facility is a near-surface disposal facility and as such the opportunities for incorporating "intrinsic robustness" into the system are limited.

Several respondents suggest that engineered robustness is mainly given by keeping technical measures as simple as possible. The drilling methods for excavation of disposal drifts can reduce the disturbed zone (ENRESA). ENRESA and OPG note that the separation between canisters and disposal drifts are selected to guarantee moderate temperatures. GRS-B points out the benefit of selecting backfill materials with experimental proof of their characteristics. Selection of a container design with ceramic inserts is made to avoid iron corrosion gas (OPG). The selection of a copper container of sufficient thickness is made to avoid sensitivity to kinetic uncertainties and pitting corrosion (SKB). One could note that other respondents gave similar examples as examples of intrinsic robustness. JNC notes that the low-permeability buffer effectively de-couples the release performance of the EBS from inherent uncertainties in future hydrological flow conditions. The material of the proposed EBS design are capable of being used in most geological settings of interest in Japan and thus are robust in their geological setting application. The (short) hazardous lifetime of the LLW inventory for the IRUS Disposal facility helped to simplify analyses (AECB).

Other examples of engineered robustness concerns measures taken to add to or improve the safety functions. The backfilling and sealing of access routes is a measure to guard against future human intrusion and repository by-pass (ENRESA). The separation of waste into disposal canisters and disposal modules limits the effect of a single canister or module performing poorly (ENRESA). HSK notes that the container and buffer are overdesigned with respect to durability for the expected conditions. The use of a corrosion resistant overpack compensates for the improbable case of poor functioning of the geological barrier (ONDRAF/NIRAS). RAWRA notes that the isolation of the radionuclides in the container has to be at least 300 yrs, and preferably 1 000 yrs. SKB notes the possibility to adapt the repository to local rock quality by selecting the positions of the individual deposition holes. USDOE notes that the TSPA-VA led to consideration of several engineered system design alternatives that eliminate or minimise the accessibility of water from drift inflow or seepage, and make the system more robust if seepage does occur. SKI suggests that the reliance on chemical retardation of radionuclides rather than physical retardation for long time-scales is an example of engineered robustness. Examples listed by BNFL include the proposed post-closure drainage system designed to ensure any potentially contaminated groundwater is directed away from the accessible environment and the vault waste form, which consists of high force compacted waste.

A5.2 Influence on the complexities in assessment models and the data acquisition needs

Generally, the quest for a robust system has often simplified the demands on model development and data acquisition. With smaller margins of safety in barrier performance more stringent demands would have to be made on the precision and verification of the data on which the performance assessment is based. There are, however, also situations where providing the proof for robustness increases the assessment complexity. It is suggested that the need for improved illustrations or demonstrations of safety and robustness often guides model development and data acquisition.

Compilation of answers

Generally, OPG, Posiva, ONDRAF/NIRAS, Nagra and SKB note that the quest for a robust system has often simplified the demands on model development and data acquisition. ENRESA found that an increase in the level robustness results in a lower level in the complexity of the assessment models and the acquisition data needs. JNC notes that the simplicity and robustness of the current design reduces some analytical complexities. BfS notes that due to the robustness against variations in the hydrogeological setting it was not necessary to acquire more hydrogeological data especially for the more complex models. HSK believes that without robustness *vis-à-vis* human intrusion a more systematic assessment of the related scenarios would be needed. With smaller margins of safety in barrier performance more stringent demands would have to be made on the precision and verification of the data on which the performance assessment is based. USDOE notes that an input to the selection of the new design was the need to reduce model complexity (and attendant uncertainty). It is believed that the new design simplifies the required modelling, although it introduces the need for new technical data and information to inform that modelling. ANDRA plans to assess the robustness of each concept taking uncertainties into account, as well as abnormal situations and how the design can resolve those disturbances. SKI notes that the physical barrier function of the silo was assumed to be intact for the first 1 000 year only, which probably made it possible to rely on a much more simplified analysis of the barrier degradation. According to BNFL there is a strong link between the level of complexity in assessment models and data acquisition programmes and the need to pursue an adequate level of robustness. The term “fit-for-purpose” is often used to justify the amount of work done on modelling, field studies, experiments, etc.

In contrast, JNC also notes that the robustness of both the geological and the EBS systems have been most evident in the large number of computational cases and supporting data necessary to show that the proposed design could be applied in many geological / chemical / mechanical settings in Japan. Thus, the computation and laboratory parameter development processes were greatly compounded. Also OPG provides examples of the opposite influence and states that the development of better models and acquisition of more data is generally driven by the need for an improved description of some feature of a disposal system, and invariably that feature has some impact on safety. That is, the need for improved illustrations or demonstrations of safety and robustness often guides model development and data acquisition. USDOE notes that the search for robustness introduces the need for new technical data and information to inform that modelling. The USNRC opinion is that complexity in the system, as well as data needs go up as a robust total system model is built. According to GRS-K, from the experts point of view, the increasing complexity of the models as well as the needs for data arose in the licensing procedure as a result of discussions on the geological site interpretation with the parties involved. The increase was not influenced by the robustness. BNFL does not believe simplistic representations are necessarily robust. An example would be the need for detailed modelling of the decay process, as peak risks often occur as a result of daughter radionuclides.

GRS-B notes that robustness was not stated as an aim itself. It was a result of the assessments.

A5.3 How robustness was communicated

Robustness is usually strongly communicated in the IPA reports. It is illustrated by “what if” scenarios, by margins of safety and by the justification of the adopted criteria in the selection of the design and site. Some respondents suggest that robustness arguments could be made even stronger in future assessments. Others see a danger in overstating robustness.

Compilation of answers

ENRESA communicated the robustness in the IPA reports by means of the description of the sensitivity analysis and the “what if” scenarios, and also by the justification of the adopted criteria in the selection of the design and site. USNRC notes that robustness is usually expressed in terms of margins of safety and in demonstrating defence-in-depth. The NCR’s performance assessments include case studies to demonstrate the performance of the system with particular barriers neutralised. Posiva supported the robustness of the canisters by the canister design analyses and the study of the normal evolution of the repository at the candidate sites, leading to the base case scenario of no consequences in TILA-99. The UK Nirex Ltd IPA report explains, for example, the benefits of siting a repository at depth in a rock of low economic potential to minimise the probability of inadvertent future intrusion into the repository. JNC notes that the overall safety case shows that most geological settings in Japan can be used with the current, highly robust EBS design, communicating a strong message of feasibility with substantial margins for optimising designs. This message permeates the H12 report and is clearly described in the executive summary. Nagra carefully defines robustness early in the safety assessment report, and the features that provide robustness of the disposal concept are discussed. However, in retrospect, the robustness of the disposal concept could have been emphasised more in the statement of confidence. SKB discusses robustness in the concluding chapters and assesses it throughout the report. ONDRAF/NIRAS sees robustness as one of the key arguments in a convincing safety demonstration. OPG (and AECB) notes that all examples given of robustness are cited in the reports. SKI notes that the confidence arguments supporting robustness were included and repeated wherever the long-term safety was discussed.

BfS and GRS-K note that there is no separate report dealing with the robustness of the site concerning the realisation of the hydrogeology in the numerical models. The robustness of the site is shown by the many different model calculations performed. GRS-B makes a similar comment. USDOE notes that the TSPA-VA did not specifically address robustness, although it was discussed in the context of several models described as having taken a conservative approach, or being insensitive to changes in a certain parameter, and therefore being robust in terms of that parameter set. BNFL tends to present arguments on robustness in a qualitative manner and to a certain extent taking a low key approach. To place too much emphasis on over-engineering or redundant barriers, etc. can lead to counter arguments such as: “if you don’t need them why do you include them (are you wasting society’s money?) and if you do really need them, are they good enough and can you prove it”.

A6. BUILDING CONFIDENCE THROUGH ITERATIVE ASSESSMENT CYCLES

A6.1 Impacts of the assessment of the confidence level of the safety case

Restrictions, motivated by unresolved issues in the IPA on the use of some disposal vaults or restrictions in waste acceptance criteria are examples where the assessed confidence level of the IPA has directly influenced the commitment involved in the next iterative stage of repository development. On a more general level, there are examples where decisions makers demand updated IPAs before they are ready to make a decision on going to a new step, such as starting borehole investigations at a few selected sites.

There are several examples where the IPA or its review has implied changes in the strategy for building the safety case. Examples of changes include taking into account a more traceable objective and better justification, to consider coupled thermo-hydro-mechanical models, to use a more systematic procedure to identify and describe the processes affecting the repository and to emphasise a systematic uncertainty analysis.

Results or reviews of IPAs have also led to requests for additional site or experimental information. Many IPAs and reviews specifically identified additional information needs.

There are also examples of changes in repository design or siting (see also Section A. 6.2). Changes could, for example, be in the form of restricting the waste stream or restricting the depth (in order to avoid highly saline water).

Compilation of answers

SKB notes that the requirement to produce SR 97 is an example of the fact that it was too large a step in the level of commitment to start the site investigations without a revised and reviewed safety assessment on the table. ANDRA notes that the foreseen dates for the two safety assessments in 2001 and 2003 did not change significantly following the assessment of the confidence level resulted from the previous IPAs. According to USDOE the TSPA-VA has not reduced the commitment for progressing to the next iterative stage, it has rather supported proceeding to the next step, as have all iterations of TSPAs to date. SKI notes that uncertainties related to impacts of gas and the consequences of a sulphate attack on the concrete led to a restriction in the use of the silo when the first license was issued in 1988. Uncertainties related to the impacts of complexing agents led to restrictions on the allowed cellulose content of waste to be accepted for deposition.

There are more examples of where the IPA has implied changes in the strategy for building the safety case. ANDRA will slightly modify its strategy to take into account a more traceable objective and better justification to reach its 2001 objective. As a consequence of the past Spanish IPAs on granite and clay formations, ENRESA will consider more physical models (e.g. coupled thermo-hydro-mechanical) to achieve more confidence in the results. In response to comments by the Federal Review Panel, OPG is currently undertaking an external review of its vault and geosphere safety assessment models and codes by independent experts. The evaluation of earlier safety assessments, where nuclide migration and worst case scenarios are emphasised, lead SKB to an approach in SR 97 with a systematic procedure to identify and describe the processes affecting the repository, a greater emphasis on a base scenario where the repository behaves as expected (given today's climate) and to emphasise a systematic uncertainty analysis. AECB notes that AECL made significant improvements in the 1996 version of the IPA based on the regulatory agency comments on the 1991 version. These improvements included using a multiple line of reasoning approach to demonstrating safety, using alternative safety indicators, and updating of modelling approaches. BfS and GRS-K note that the Konrad assessment was not part of an iterative process, but that each technical report supporting the Plan was discussed with and reviewed by the licensing authority and its respective consultants. Based on review comments, radionuclide migration calculations had to be carried out in addition to the evaluation of the groundwater movement. GRS-B has considered changing scenarios. The TSPA-VA experience lead USDOE to a re-evaluation of the safety case revising it to incorporate both the need for defence-in-depth and a new design. SKI notes that the issues most extensively discussed during the review resulted in modifications on most aspects of the repository, e.g. the design, the safety case and the waste acceptance criteria (see above). BNFL notes there have been developments to the strategy for building the safety case as a result of feedback from the UK Environment Agency on interim information supplied by BNFL. This led to the adoption of a more formal systematic approach to radiological safety assessment using recognised procedures and tools such as FEP lists and interaction matrices.

Results of IPAs have also led to requests for additional site or experimental information. A few organisations provide specific examples. SKB notes that more confidence is needed on modelling fuel dissolution, backfill evolution, and thermal conduction between the canister and buffer before buffer saturation, and in describing initial canister defects. JNC notes that the H3 IPA released in 1992 identified a series of technical areas that needed additional research in order to provide geological data specific to the Japanese geological setting for the next round of feasibility studies. As a result of this first study a series of pilot- or engineering-scale experiments, along with the experimental facilities and a state of the art hot facility for developing solubility and retardation parameters for IPAs, were developed and used. USDOE notes that the TSPA-VA and the new design contributed to a reprioritisation of needed information from site characterisation (saturated zone properties, colloidal transport, seepage into drifts) and materials testing activities. GRS-B notes that if the consequences were not acceptable, further experimental investigations (e.g. to demonstrate a postulated value for the permeability of backfill or to develop models for dissolution and precipitation of different mineral phases in the special chemical environment of the near field) were initiated. SKI notes that a condition for the operation permit of the repository was that additional research should be carried on the effect of complexing agents.

There are also examples of changes in repository design or siting (see also Section A.6.2). AECB notes that the proposed waste streams for IRUS were restricted to those with well-defined radionuclide and contaminant inventories. UK Nirex Ltd used the spread of results obtained from the six illustrative models to inform the approach for other generic studies for example an assessment to form the basis for waste packaging advice. Uncertainties related to the performance of buffer and backfill in case deep, very saline groundwaters would penetrate into the repository have made Posiva recommend that a KBS-3 type repository can only be placed at a restricted repository depth at some sites and to explore potential needs for design changes. GRS-B has considered design changes. USDOE notes that the TSPA-VA experience led to a change in the design with more emphasis on defence-in-depth.

According to ONDRAF/NIRAS no such a situation has occurred in the disposal programme. Nagra has not taken any action since their crystalline programme is currently awaiting the regulatory review and, at the moment, the work focuses on the Opalinus Clay option. According to UKEA and USNRC the question is not applicable to them.

A6.2 Examples of the interplay between PA/SA and the technological development of the repository

A6.2.1 What has mostly driven design changes in your programme?

Design changes are driven by a combination of IPA results and technical development and feasibility studies. Examples of design changes which have been, at least partly, driven by results from IPAs or consideration of long term performance include:

- selection between alternative designs;
- restriction of waste acceptance for different vaults;
- modification of vaults in order to handle gas production;
- the repository lay outs in order to maximise the effective thickness of the clay barrier;
- changes of backfill and sealing to account for high salinities;
- abandonment of difficult-to-predict canister materials;
- searching for more multiple barriers and defence-in-depth designs.

Engineering development work and general scientific progress lead to new designs or may imply needs to change previous designs. Cost issues and the reductions in the uncertainty linked to certain data are important reasons for design modification. Changes in canister material or design may be driven by results from supporting R&D and engineering feasibility studies. Also requirements for construction and operational safety, uniformity of waste packages for different possible repository environments, engineering feasibility and meeting design goals for thermal and other properties of the system are also very important inputs to selecting from among options that assure long term safety.

Compilation of answers

A few directly state that design is driven by a combination of IPA results and technical development and feasibility studies. JNC notes that design changes have been motivated by the ever present need to balance robustness in the safety assessment with the projected engineering/ construction feasibility and costs. Posiva notes that site characterisation; engineering design, supporting R&D and IPAs are made in close interaction. OPG notes that repository design is still at an exploratory stage and different options are being evaluated. Both the results of IPAs and a re-assessment of engineering feasibility have affected design. Nagra notes that a combination of several disciplines and criteria have influence and will continue to influence design, but IPAs are one of the most important aspects. SKI notes that the issues most extensively discussed during the review resulted in modifications on most aspects of the repository, e.g. the design, the safety case and the waste acceptance criteria. For example, by introducing the rock vaults and by modifying the silo one could handle the problems with gas formation resulting mainly from corrosion of steel reinforcement.

There are many examples of design changes, which have been, at least partly, driven by results from IPAs or consideration of long-term performance. ANDRA notes this is generally the case. ENRESA states that in the future integrated geological information, repository designs and R&D data will be emphasised so that facility designs can be optimised. ONDRAF/NIRAS notes that in a few cases the results of PA have induced changes in the repository design, for example all vertical repository lay outs (e.g. in vertical boreholes from a horizontal main gallery) have been abandoned, in order to maximise the effective thickness of the clay barrier. Posiva notes that presently there are several experimental and modelling studies under way considering whether the highly saline groundwaters found at great depths imply needs for design changes in the backfilling and sealing. GRS-B states that the design of technical barriers, which are used to enhance and demonstrate the long-term safety of the system, is driven mainly by the results of IPAs. SKB abandoned ceramic and titanium canisters based on the difficulty of proving long-term material properties (e.g. delayed fracturing). USDOE notes that the evaluation of TSPA-VA results in light of regulatory expectations regarding multiple barriers and defence-in-depth, and in light of the need for a robust system that assures safety by its very nature, led to a new design.

Engineering development work and general scientific progress lead to new designs or may imply needs to change previous designs. ANDRA notes that changes in cost issues (ALARA principle) and a reduction in the uncertainty linked to certain data (including site data) are important reasons for design modification. ONDRAF/NIRAS notes that most changes in the repository design are driven by research results or by problems encountered in the technical feasibility assessment. Posiva notes that design changes, for example in the inner structure of the copper canister, resulted from supporting R&D and engineering feasibility studies. BfS and GRS-K state that the design of their repository depends on requirements for construction and operational safety, whereas the long-term safety assessment of the KONRAD mine does not rely on the design of the repository. USDOE notes that engineering feasibility and meeting design goals for thermal and other properties of the system are also very important inputs to selecting from among options that assure long term safety. ENRESA notes that in the past, the bulk of the effort in the development of the disposal concepts has been given to the systematisation and optimisation of the design with the aim of defining common design elements for the three Spanish candidate host rocks (granite, clay and salt). According to BNFL, there was a major facility design change at the Drigg site in the late 1980s, with the decision to change from disposal of essentially loose wastes in simple earth trenches with a low permeability clay base to a disposal system based on a standardised waste form and engineered concrete vaults. This change was in line with developing international best practice in site operations and not driven by radiological safety assessment results.

RAWRA proposed minimum separation distances between waste emplacement holes and corridors in its IPA based on heat flow considerations. UK Nirex Ltd made a generic study, which was not part of an iterative assessment cycle in the standard sense. HSK, AECB, UKEA and USNRC note this to be a proponent’s question.

A6.2.2 What has mostly driven site selection in your programme?

Most organisations consider both IPA results and socio-political constraints to drive site selection. Selected sites need to fulfil safety requirements. Also favourable aspects of sites have and will be factored into the site selection decisions. Socio-economic factors including public acceptance are important reasons for siting. Some sites are selected partly because they are located in proximity to other nuclear installations. Local acceptability is required in most countries.

Compilation of answers

Most organisations consider both IPA results and socio-political constraints. Nagra notes that a combination of several disciplines and criteria, with a strong impact from IPA results have influenced (and will continue to influence) site selection. OPG notes that it is expected that the site selection for disposal will be driven by the results of IPAs, but also environmental protection, voluntarism shared decision making, openness and fairness. SKI suggests the SFR site be selected based on the characterisation and general assessment of the hydrology and the geology in a number of municipalities that already had nuclear installations.

Still, the results of IPAs also affect siting decisions. ENRESA, Posiva and others require that sites need to fulfil safety requirements. In France the different sites are assessed for their geometrical and geological characteristics and this will be factored into the final site selection process (ANDRA). JNC notes that no site selection process has been started, but the results of the IPA will be considered as site selection guidance is developed. BfS notes that the main favourable features of the site were major factors in the decision-making process. Also GRS-K notes that the Konrad site was chosen after suitability investigations because of its main favourable features (very dry mine, thick low permeable clay layers above the repository horizon). The SKB IPAs demonstrate that normal conditions in Swedish granitic bedrock are suitable. USDOE notes that the past Congressional decision came after nine Environmental Assessments were completed for sites in three geologic settings and if the selected site does not pass the test for safety, Congress will decide a new course of action.

Socio-economic factors including public acceptance are important reasons for siting. The French site-selection process undertaken in 1992-94 was mostly driven by political considerations (ANDRA). The Mol site was been selected in the first place because of the presence of the Boom Clay in the underground, but also due to the presence of the nuclear research institute (ONDRAF/NIRAS). Posiva notes that among the sites fulfilling the siting and safety criteria, mainly environmental and social factors, and local acceptability have driven the final selection. AECB suggests that AECL wanted to construct the IRUS vault at the Chalk River Laboratories site where the wastes are currently stored. Prospects for public acceptance are important. In the US it was a political decision to concentrate on one site (USDOE).

USDOE notes that site selection is not, in the legal sense, a current issue in the US programme. There was no answer from RAWRA. HSK, UKEA and USNRC note that the question is directed to proponents. The UK Nirex Ltd study was generic and not part of an iterative assessment cycle in the standard sense.

A6.2.3 Siting criteria

Some organisations have presented site exclusion criteria or discuss desirable and unfavourable properties of the rock. It should of course be noted that all of these examples might be concept, site and design specific. They are not generally applicable.

Compilation of answers

Some organisations have presented site exclusion criteria or discussed desirable properties of the rock. Partly based on the SR 97 results, SKB will publish a special report on how various site data will influence the functioning of the site during 2000. The report discusses requirements for the rock, desirable properties of the rock, and criteria to be used in different phases of the site selection process. HSK has issued statements on the desirable features of a site selected for a repository.

ENRESA applies a “respect distance” between emplacement vaults and fracture zones. OPG states that sites with few major lineaments, widely spaced major lineaments and few open fractures in the rocks between the lineaments, absence of post-glacial faults and a location far from potential regional-scale faults are generally desirable. Nagra notes that long respect distances to larger features makes the site more favourable (but respect distances were not explicitly included in Kristallin-I report).

JNC suggests siting should strive for avoiding disruptive events from volcanoes, earthquakes, uplift and erosion, along with extreme groundwater system fluctuation driven by climate change. The developed scientific basis for understanding the degree of impact on a repository from sites in proximity to these disruption sources is likely to form the bases for exclusion criteria when the implementation of a repository selection process proceeds. OPG notes that a site lacking some essential characteristic such as a low level of seismic activity should be avoided. Posiva will avoid depths with highly saline water due to uncertainty in the performance of buffer and backfill.

OPG notes that sites exhibiting an unacceptable characteristic such as the presence of an endangered and valued ecosystem species would not be suitable.

According to AECB, AECL staff notes that the ability to confidently model contaminant transport at the site, and the availability of site data have been identified as desirable site characteristics as a result of PA/SA work.

OPG notes that a larger number of desirable site characteristics have been identified, including a regional upland location, areas with low topographical relief, no mines or areas with potentially valuable minerals in the general vicinity, and a large area extent and depth of plutonic rock with relatively uniform properties. OPG also notes that an area with a large outcrop is desirable. Nagra notes that the results of Kristallin-I are used to identify host rock characteristics that provide a favourable environment for the engineered barriers. These include the specification of an approximate upper limit to the desirable range of groundwater flow rates in the vicinity of the repository and groundwater chemical characteristics (near neutral pH, reducing, low to moderate salinity). Characteristics are also identified that provide adequate overall system performance, assuming poorer than expected performance of the engineered barriers. These include the specification of a minimum migration distance in good quality rock, an approximate upper limit to the desirable range for the ratio of groundwater flow rates to the spatial density of open channels and the need for a mineralogy and groundwater composition to favour radionuclide retardation.

USDOE notes that site exclusion criteria were contained in the Department of Energy’s Siting Guidelines, a publicly promulgated regulation (Code of Federal Regulations, Chapter 10 Part 960, or 10 CFR 960). The criteria implemented were Nuclear Regulatory Commission criteria, previously published in that regulator’s rule governing repositories (10 CFR 60). These two regulations are being rewritten to remove their criteria for site comparison as part of site selection, and to focus on system safety.

No answer, or not applicable for ONDRAF/NIRAS, RAWRA, UK Nirex Ltd, BfS, GRS-K GRS-B, BNFL, UKEA and USNRC.

A6.2.4 Use of FEPs list to guide siting?

Only a few organisations have directly used FEPs lists to guide siting. There are examples where siting checklists were prepared based on such lists. However, in general FEPs are considered in the IPA and the use of FEPs is indirect through the use of IPA results or considerations in guiding siting.

Compilation of answers

Prior to the selection of Initial Design Options, ANDRA used a list of relevant events that might be seen as a list of FEPs. This list of events was used to select the failure scenarios that were used in the preliminary quantitative assessment to design components. OPG notes FEP lists have been used both formally and informally throughout the Canadian nuclear fuel waste management programme. The expectation is that they will continue to serve a role during site selection, design, construction, operation, decommissioning and other phases of disposal. Nagra and HSK note that in the case of the site selection process for low and intermediate level waste repository, check lists for the comparison of different sites were based on certain relevant FEPs.

Most organisations (ENRESA, JNC, ONDRAF/NIRAS, Posiva, BfS, GRS-K, GRS-B, AECB, SKB, SKI, and USDOE) have not directly used FEP-lists in guiding site selection, but they have and are considering FEPs in the IPAs. For example, JNC notes that FEP-lists were an integral part of defining both calculation cases and parameter development needs, which translated into laboratory and database development programmes. BfS and GRS-K note that formal FEP-lists did not exist a priori, but were developed site specifically and within the licensing process. Still, requirements which sites had to fulfil existed. SKB notes that the selection of the rock type and basic conceptual design was done in parallel with the early identification of FEPs, and at each succeeding PA and design revision, the earlier FEP lists have been used as starting points. UKEA has considered the use of FEP databases and the NEA International FEP Database in particular, as a basis for technical review of a safety case. BNFL notes FEP-lists are now used as a key component of the radiological safety assessment and in addition the Engineering Performance Assessment includes the identification of key events and event sequences using detailed fault and event trees as part of the process of developing an optimised closure system.

A7. REFERENCES

AECL (Atomic Energy of Canada Limited). (1994a). Environmental impact statement on the concept for disposal of Canada’s nuclear fuel waste. Atomic Energy of Canada Report, AECL-10711, COG-93-1. Available in French and English.

AECL (Atomic Energy of Canada Limited). (1994b). Summary of the environmental impact statement on the concept for disposal of Canada’s nuclear fuel waste. Atomic Energy of Canada Limited Report, AECL-10721,COG-93-11. Available in French and English.

AECL (Atomic Energy of Canada Limited). (1996). “Preliminary Safety Analysis Report (PSAR) for the Intrusion Resistant Underground Structure (IRUS)”, AECL-MISC-295, Rev. 4.

Bailey L.E.F. and A.K. Littleboy, (2000). The UK Nirex Ltd Repository Concept: Evaluating Performance, UK Nirex Ltd Report N/011.

Ben Slimane K., Guilloux Y., Chupeau J., Poisson J.B., Description des concepts de stockage, C NT AHVL 99-020, juillet 1999.

Ben Slimane K., Poisson R., Chupeau J., Krieger J.M., Thorner P., Guillaume S., Guilloux Y., Choix des concepts préliminaires: synthèse justificative, C NT AHVL 99-017/D, mars 1999.

BfS (1990) Plan Endlager für radioaktive Abfälle, Schachtanlage KONRAD, Salzgitter, 9/86 in der Fassung 4/90 (in German).

BNFL, 2000. Status Report on the Development of the 2002 Drigg PCSC. BNFL, Risley, UK.

De Preter, P., Marivoet, J. and Minon, J.-P., (1999) A deep radioactive waste repository in the Boom Clay: the long term safety functions and robust safety indicators. Proceedings ENS Topseal '99, Antwerp, Belgium, 10-14 October 1999, Volume I, 231-237.

DOE (U.S. Department of Energy) (1998). Viability Assessment of a Repository at Yucca Mountain. DOE/RW-0508. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

DOE (U.S. Department of Energy) (1999). Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada. DOE/EIS-0250D. Volumes I and II. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

Duerden S.L., Smith R.E., Sumerling T.J. and Yearsley R.A. (1996) Regulatory Assessment of an Applicant’s Long-term safety case in the UK, 7th International High Level Radioactive Waste Conference, Las Vegas.

ENRESA-2000. Evaluacion integrada del comportamiento y la seguridad de un almacenamiento geologico de residuos radiactivos en roca granítica” (in preparation).

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski and A.G. Wikjord. (1994). The disposal of Canada’s nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report, AECL-10717, COG-93-7.

Goodwin, B.W., T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, J.G. Szekely, A.G. Wikjord, D.C. Donahue, S.B. Keeling, C.I. Kitson, S.E. Oliver, K. Witzke and L. Wojciechowski. (1996). The Disposal of Canada’s Nuclear Fuel Waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 5: Radiological Assessment. Atomic Energy of Canada Limited Report, AECL-11494-5, COG-95-552-5.

Hoorelbeke J.M., Chupeau J., Lagrange M.H., Plas F., Dutzer M., Hoteit N., Tevissen E., Altmann S., Trouiller A., Voinis S., de Franco M., Pierlot S., Guilloux, ben Slimane K., Poisson R., Thorner P., Garnier J., Pepin G., Synthèse des Options Initiales de Conception d’un stockage géologique des déchets (HAVL), C RP AHVL 98-203 – 1998.

IAEA, (1992), “Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards”, IAEA Technical Report Series 332, International Atomic Energy Agency,Vienna.

IAEA, (1993), Radioactive Waste Management Glossary. International Atomic Energy Agency, Vienna.

IAEA, (1995), “Clearance Levels for Radionuclides in Solid Materials”, IAEA Safety Series No. 111-G-1.5, International Atomic Energy Agency, Vienna.

IAEA, (1998), Draft IAEA Safety Glossary (for comment). International Atomic Energy Agency, Vienna, April 1998.

IAEA, (1999), “Long-term releases from solid waste disposal facilites: the reference biosphere concept”.

IAEA Draft TECDOC, BIOMASS Theme 1, Working Document BIOMASS/T1/WD01 1999. International Atomic Energy Agency, Vienna, 1999.

JNC (2000): H12: Project to Establish the Scientific and Technical Basis for HLW Disposal in Japan, Project Overview Report, JNC TN-1410 2000-001.

Metcalfe D. E., 1999. Letter to G.M. Dolinar (AECL) dated 1999 April 14 entitled “Application for a Construction Licence for an IRUS Disposal Unit”, CNSC file 37-16-1-4, #614112.

Nagra (1994) Kristallin I Safety Assessment Report, Nagra NTB 93-22, July 1994, (can be obtained from Nagra, Hardstrasse 73, 5430 Wettingen, Switzerland).

NMU, (1997) Endlager für radioaktive Abfälle, Schachtanlage KONRAD, Salzgitter. Gutachten, Teil 2: Langzeitsicherheit. TÜV Hannover on behalf of NMU.

NRC (1999) Sensitivity and Uncertainty Analyses for a Proposed HLW Repository at Yucca Mountain, Nevada Using TPA 3.1 NUREG-1668 (2 volumes). Washington, DC: US Nuclear Regulatory Commission.

OCRWM (Office of Civilian Radioactive Waste Management) (2000). Repository Safety Strategy: Plan to Prepare the Postclosure safety case to Support Yucca Mountain Site Recommendation and Licensing Considerations, TDR-WIS-RL-000001, REVISION 03, JANUARY 2000.

ONDRAF/NIRAS (in preparation), SAFIR-2, Safety Assessment and Feasibility Interim Report 2, ONDRAF/NIRAS.

Ruokola E. (ed. 2000): Posiva's application for a decision in principle concerning a disposal facility for spent nuclear fuel; STUK's statement and preliminary safety appraisal. Helsinki, March 2000. Radiation and Nuclear Safety Authority, Report STUK-B-YTO 198.

SKI, 1988, Granskning av slutförvar för reaktoravfall, SFR-1, SKI Report 88:2, SKI, 1988. In Swedish, Swedish Nuclear Power Inspectorate.

SKI, 1992, Utvärdering av SKB:s fördjupade säkerhetsanalys av SFR-1, SKI Report 92.16 and SSI-report 92-07, In Swedish .Swedish Nuclear Power Inspectorate and Swedish Radiation Protection Institute

SKB, 1987, Slutförvar för radioaktivt driftavfall – SFR 1, Slutlig säkerhetersrapport SFR-1, In Swedish, Swedish Nuclear Fuel and Waste Management Co. Stockholm, Sweden.

SKB, 1991, SFR-1: Fördjupad säkerhetsanalys, SFR arbetsrapport 91-10, In Swedish, Swedish Nuclear Fuel and Waste Management Co. Stockholm, Sweden

SKB (1999), SR 97 – Post-closure safety. Main report, Volumes I and II; SKB Technical Report, TR-99-06. Swedish Nuclear Fuel and Waste Management Co. Stockholm, Sweden

Storck R, B. Boese, J. Brenner, H.-J. Herbert, T. Kuehle: (2000), Endlager Morsleben: Untersuchungen zur Entwicklung von Stillegungskonzepten: Porenspeicherkonzept und Abdichtungskonzept. (in German, internal report), GRS-A-2779, Maerz 2000

Sumerling T.J. (1999), Interpretation of Optimisation in the Context of a Disposal Facility for Long-lived Radioactive Waste, Environment Agency R&D Technical Report P259, obtainable from WRc publications Swindon, email: publications@wrcplc.co.uk.

UKEA, (1997), Environment Agency, Scottish Environment Protection Agency and the Department of the Environment for Northern Ireland, Disposal Facilities on Land for Low and Intermediate Level Wastes: Guidance on Requirements for Authorisation, Environment Agency, Bristol, January 1997.

Vieno T. and Nordman H. (1999), TILA-99, Safety assessment of spent fuel disposal in Hästholmen, Kivetty, Olkiluoto and Romuvaara. Report Posiva 99-07. March 1999.

Voinis S., Pierlot S., Safety Approach SUR NT ADSU 99-052/A, July 1999.

Yearsley R.A. and Sumerling T.J. (1998), The interpretation of optimisation in the context of disposal of long-lived radioactive waste: Work by the UK Environment Agency, International Symposium on Radioactive Waste Disposal, Stockholm, 1998.

Appendix B

MAKING ORAL PRESENTATIONS ABOUT A SAFETY CASE

B. MAKING ORAL PRESENTATIONS ON THE SAFETY CASE

The IPAG-3 Questionnaire responses contained many references to experience with presentations of IPAs. Some indicated that they believed there had been effective communication with the intended audience, and others indicated that effectiveness was questionable, and at best not quantifiable.

The Questionnaire focused on media used in communications, the technical tools for communication, and the resulting list of communication methods. Some stated that publication in refereed journals was important, and pursued publications as a way of positively influencing the general scientific community. Some stated that a hierarchy of documents, written to reach different audiences, was needed.

However, publishing papers and documents, and the mechanics of writing effective illustrative material is necessary, even vital, but it is not where help is needed among IPAG-3 participants. IPAG-3 participants were interested in sharing experiences in making presentations to groups of stakeholders and at public meetings, and ensuring good communications between the parties involved. A subgroup of IPAG-3 participants discussed these issues at the Toronto IPAG meeting in May 2000, and elaborated on their collective experience in communicating and presenting safety cases and IPA results to different audiences.

This appendix presents the results of the work of this subgroup of IPAG-3 participants. Clearly, it is not the definitive work on the subject of communicating and presenting safety cases and IPAs. In fact, it is only a first step towards sharing the international experience in this area, and is part of the effort of coordinating the work of the IGSC, of which IPAG-3 is a part, with the work to be undertaken by the newly constituted NEA Forum on Stakeholder Confidence (FSC).

B1. Prerequisites before communicating the results of safety cases and IPAs

First and foremost, technically competent and comprehensive safety cases and IPAs are needed as the core subject for presentation and communication, whether the presentation is to a highly technical audience or not. ***The safety case should be well argued and supported, should state its purpose, and should place itself into a programme context: identifying where it sits in the decision-making plan, and showing where it is on the decision-making schedule.***

There are three reasons for suggesting this should be done in the safety case documentation itself, although it can certainly also be shown in brochures or meeting handouts or announcements:

1. The presentation of a safety case should not have to reach outside the safety case documentation to put itself into the decision-making context.
2. The safety case should indicate what comes next, in terms of additional data gathering or other decisions, so that the presenter can make a clear statement on the role of the

audience: are they simply being informed, or are they also being consulted in a meaningful way?

3. The safety case is the starting point for related presentations, brochures, etc., intended for different audiences, and its comprehensiveness assures consistency in those products.

If the safety case makes an argument for compliance with regulatory criteria, the regulations and the regulator's role need to be explained in the documentation, as well as in presentations. This will help to inform the various stakeholders that independent oversight is built into the repository assessment and development process to ensure that society is protected against undue risk.

Addressing the regulatory criteria is also important because it documents the implementer's interpretation of the regulations. This gives the regulator an opportunity to correct that interpretation if necessary. This is particularly important for programmes where the licensing decision is still far in the future. In such cases, the preliminary safety cases serve to document the ways in which the spirit and details of the regulations were interpreted at the time the safety case was assembled.

It is important that the decision-making process can be explained, and it is even more important that it can be credibly described as being both open and fair. It is important that the audiences get the sense that the safety case and its IPA represent an honest attempt at ascertaining safety, and that the process is a candid attempt to assure safety. The documentation needs to be able to convey, by openness and forthrightness in its presentation style and in anticipating questions, the idea of the safety case being a trustworthy assessment that is part of a fair and well-defined societal decision-making process. If the safety case is being presented to an audience, the presenter must be able to convey these same qualities, and in addition must be able to deal with comments and questions in a way that reinforces these messages of openness and fairness.

In addition to being aware of all of the above, in the context of making a presentation of a safety case, the presenter needs to be technically competent to discuss the many aspects of the subject matter being addressed in the safety case, including its IPA. The presenter should be able to answer questions on all aspects of the safety case, at a level of detail appropriate to the audience. To the extent possible, the IPA results should, in the greater context of the safety case, be explained in terms of its role in furthering the objectives of the repository development programme. This role would include serving as a basis for regulatory dialogue and decision making, and providing a basis for stakeholder or public dialogue and involvement.

Finally, it is important for the presenter, in case of a presentation, and an author, in the case of document preparation, to be able to have confidence in the safety case that is being presented. Confidence requires trust in the societal context, in the management of the programme, and in the workers doing the data gathering and analyses. More than that, confidence requires a degree of comprehension of what the arguments are for safety, and how the data and analyses cited support those arguments. If either a document author or presenter lack this type of trust- and comprehension-based confidence, it is very likely going to be impossible to convey confidence to any reading or listening audience.

B2. Identifying potential audiences and stakeholders

Audiences and stakeholders are not presented in any particular order in this section. The intent here is to characterise the needs of these audiences. These needs can be met through published materials only in part. The emphasis here, and in the remainder of this appendix, is on information on a safety case that is being presented to a live audience. The primary goal of such a presentation is to increase audience comprehension. If possible, trust in the process being implemented can also be conveyed, or increased if there is already some degree of trust established.

The Public

In some English-speaking nations, experience has shown that the public, especially the more impacted local public, does not like to be described as a "stakeholder." The perception may be that stakeholders are defined in English as a person or organisation having something to gain from the existence of the facility for which the safety case is being prepared. In other locales, however, it appears that the local public demands to be viewed and treated as a stakeholder since what is at stake is their well being. Some portion of the public, especially locally, may feel that this facility is presenting them with an uninvited risk in order to reduce risks elsewhere. Others may be more receptive to the proposed facility, because they consider it to be a low risk undertaking with a number of potential benefits in terms of the local economy and infrastructure improvement.

There are also other viewpoints within the diverse group called the public, including those who are opposed to any type of activity based on taking advantage of the thermal or other properties of radioactive materials. Some may oppose a disposal facility simply because the lack of suitable disposal facilities makes the operation of nuclear power generating stations and other nuclear activities more problematic. On the other hand, others may feel positive about nuclear power. These members of the public may believe that environmental issues such as global warming and socio-economic issues such as over-reliance on fossil fuels demand the maintenance of the nuclear alternative.

All public concerns, regardless of the source, must be treated seriously, respectfully, and calmly. Impatience or exasperation from the presenter will reflect poorly on the presenter, regardless of the motives or tactics used by intervenors. There will likely be observers in the audience who do not agree with the viewpoints of the intervenor, but will, as human beings, be very interested in how the intervenor is perceived and treated. It is a good idea to have a neutral meeting-moderator to keep order in an even-handed way.

Local and non-local publics may have differing concerns and viewpoints. The important point is to recognise that a presentation of safety case material may need to appeal to all these viewpoints because a meeting in a public setting is likely to have all of the above, and even other, viewpoints represented.

A special case audience in some nations may be aboriginal peoples. Diet and water-use habits, as well as lifestyle conditions specific to minority peoples, may differ markedly from their neighbours, making them suspicious of claims that they have been fully considered in the biosphere assumptions of IPAs and are being adequately addressed in the larger safety case. In the aboriginal religious traditions and concepts of some populations, the earth is considered to be sacred. Safety analyses and technical arguments cannot address the fundamental aboriginal views on the perceived desecration of the earth if used for radioactive waste disposal.

Public Officials

As with the public, public officials will represent a wide spectrum of viewpoints, and will be even more conditioned by the nature of their jurisdiction and its proximity to the proposed facility. It is important to achieve the same measure of communications success, if the topic is a safety case, as described above for the general public. It is also important to make materials available to public officials for use in discussing the proposed system and its degree of safety or risk with their constituents. These materials and presentations should be provided regardless of the public official's public or private stance toward the proposed disposal system.

Internal Audiences

A special case audience is the internal management and workforce of a repository programme or even a regulatory programme. It is important that management and co-workers be kept up-to-date on safety case developments, and become knowledgeable about the state of the work and the implications of the IPAs analyses, to focus future efforts on what really matters to performance. Management decisions not fully informed by the current status of work are higher-risk decisions than they need to be. Workers need to feel comfortable about the work they are doing. Comprehending the place of their work in the overall safety case is a way of developing comfort and at the same time promote the ability to communicate what they are working on to others. Internal audiences are also good practice audiences in terms of the types of questions that may be asked in public meetings, and the feedback received on the communication effectiveness of words and illustrations.

Utilities and Other "Customers"

Waste generators that will be dependent on the facility for the disposal of their waste are stakeholders. They have a fiscal and material involvement with regard to ensuring the long-term safe management of the wastes they generate. There will be a higher acquaintance with nuclear topics and issues in this audience, but not necessarily a greater acquaintance with things such as the modelling of a natural system enclosing an engineered barrier system over time frames of thousands of years. Therefore, a safety case may be a new idea for many, even in this audience.

It is important that waste generators allow the safety-assessment-related work to be done honestly and openly. In some nations the work is done by an independent agency, in others it is done inside a waste generation company, or in a corporation owned and controlled by a variety of directly interested parties. It does not matter as long as those charged with characterising the site, designing the system, and evaluating the safety of that system are expected and required to do their work competently, honestly, and openly. Also, ***it is important that the regulatory authorities, representing the interests of public safety, be involved in the process earlier rather than later.*** They need to be seen as independent overseers of the quality of the work and the credibility of the safety case.

Regulatory Authorities

As noted in the IPAG-2 report [NEA, 2000-a], extensive ***communication and dialogue is required between implementers and regulators throughout the safety case development and review process.*** Typically, some of the interactions between implementers and regulators will occur in public fora, and as with all interactions, it is important that discussions be both frank and respectful. The implementer needs a strong and independent regulator for the public to have faith in the societal decision-making process. Further, the societal process will be called into question if either side acts in a way that may be perceived as unfair toward the other. Professional decorum and correct social behaviour are required on both sides.

Some IPAG-3 participants expressed the view that it is helpful to both parties if the regulator performs independent assessments to assist in its evaluation of the implementer's work. These participants believe that an independent regulatory assessment capability lends credibility to the efforts of both the regulator and the implementer.

Governmental or Other Oversight/Peer-Review Groups

Some governments appoint oversight groups of experts to give society the benefit of additional scrutiny of the implementer's assessments and proposals. Further, programmes may call in outside experts themselves, in the form of peer reviewers or as individual or group technical advisors. Presentations to these types of groups will generally focus on technical issues in a rigorous and comprehensive manner. Typically, the members of such oversight or advisory groups are drawn from the scientific community at-large. Therefore, ***it is important to be able to impart a justified sense of scientific and engineering competence, and of dedication to doing the right work for the right reasons.***

Scientific Community

IPAG-3 participants note that it is necessary *to engage* the scientific community, so that ***the scientific community can be a participant in the societal decision-making process***. Without the support of the scientific community, obtaining public acceptance will be difficult if not impossible. However, scientific community support alone will not guarantee public acceptance.

The scientific community audience may best be reached through publishing in scientific and engineering journals, and through presentations at professional society meetings. Having recognised experts from the scientific community review work or give advice, as mentioned above, is another way of engaging the scientific or engineering communities. However, in engaging a competent scientist or engineer to give advice, it must be recognised that critical comments will be provided. The comments will need to be considered and addressed appropriately, even if the implementer believes that the underlying issues raised are not important to long-term safety.

B3. Addressing the intended audience in preparing presentations

Having considered the various potential audiences, identifying the purpose of the meeting helps to select the primary audience from the list, and vice versa. Most meetings with interested parties will tend to have a mixed audience. If the audience is mixed (for example a meeting with a peer review group in a public setting), ***it is necessary to identify and address the primary audience***. A presentation cannot be all things to all audiences; hence it must be tailored to the primary audience. However, awareness of potential sensitivities of secondary audiences may help structure a presentation to coincidentally aid the understanding of that audience.

Characterising the primary audience involves ascertaining their expectations, their technical information needs, interests and sophistication. Experiences with the audience, and directly discussing or planning the meeting with representatives from that audience, serve to make presentations and exchanges more productive.

In dealing with a public information meeting or other public exchange, it is important not to underestimate the audience's technical sophistication. To talk down to an audience, or even to be perceived as talking down, hinders communication and polarises the audience and presenter. Further, it is important to try to understand the audience's issues and perspectives regarding the disposal facility.

In addition to technical content, the potential primary audience needs to be consulted regarding the format and style of the meeting. There is a big difference between a series of presentations followed by questions, and a round-table format with short opening statements and presentations, and the bulk of the time dedicated to questions and answers or other formats for open exchanges and discussions.

The time that is to be available for a presentation or exchange is an extremely important part of planning for a presentation to any audience. All audiences, no matter how technical or interested, are human beings with limits on how much material they can assimilate and how long their attention span is optimal. On the other hand, a short time period for a presentation is an opportunity to stay focussed on the primary message.

Finally, it is important to maintain flexibility, to be able to listen to the audience and to change the emphasis of the presentation to suit the expressed needs of the audience if it is different from that originally assumed. Interacting with representatives of the primary audience as part of the planning for the presentation is a good way to prevent this from occurring, but circumstances and events can also change the needs of that audience.

B4. Defining the message

Safety Case Presentation Messages

It is recommended that there be only one "main message" for a given iteration of a safety case. The main message needs to be identified based on the diverse range of audiences and stakeholders that will be reading and reviewing the safety case. There may be as many, or more, sub-messages as there are components and sub-models, but all of these sub-messages need to be readily couched into the context of the larger message. However, attention is required to ensure that there are no conflicting or non-supportive sub-messages.

As repository programmes have matured, the sophistication and complexity of safety cases and the sophistication of stakeholders have increased. It is partly in recognition of this fact that this report discusses such things as multiple lines of reasoning and other attempts to become more sophisticated in making a complete safety case, rather than just a system performance calculation.

Communicating the various aspects of a safety case will require multiple presentations, because a safety case is a complex technical integration that cuts across a multitude of scientific and engineering disciplines. Each presentation would need to have one or more sub-messages that are placed into the context of the overall, "main" message of safety. The messages given in presentations should be selected based on the roles, concerns and interests of the primary intended audience.

At every level of publication and presentation, the "main" message from the safety case should be clearly presented in the introductory material or introduction. The "main" message of safety and the accompanying issue of confidence should be supported by the conclusions. Messages can differ greatly in terms of technical detail, however efforts are required to avoid the appearance of using the safety case to give different messages to different audiences.

Preparation

The following bullets are a check-list of issues for consideration when preparing a presentation:

- Tailor presentation to primary audience in terms of length, emphasis, detail, and packaging.
- Show what is to be explained (system features description).
- Show how the system works (system process and events description, starting with the expected evolution of the system).
- Explain modelling process (integration of FEPs/abstraction of complex calculations).
- Explain basis for modelling (site investigation, design, materials testing, and emphasise commitment to continual improvement).
- Show the expected safety and its uncertainty (system safety indicators; show expected, undisturbed performance first, show potential results of low probability events separately).
- Balance the uncertainties associated with long time frames, large spatial domains and complexity of the disposal system with confidence that the system will be safe for the hazardous lifetime of the wastes.
- Demonstrate the complementary roles of the engineered and natural barriers and the robustness of the disposal system.
- Maintain consistency between the safety case and supporting documentation.
- Use specialised terms and acronyms judiciously.
- Provide evidence that the safety case methods, tools and procedures are correct, well accepted and appropriate for their intended use.
- Place the regulatory criteria, design basis, site features and assessment results into context and perspective with those of other national programmes.
- Identify and address reviewer/regulator/public issues and concerns in a direct and open manner.
- Explain what is needed to be more sure, and show there is ongoing work and plans for future work to obtain that information.
- State whether or not there is sufficient certainty to meet the goals of the safety case in terms of the decisions that need to be made (a “statement of confidence” in a specific context, saying that because of these results and what is known, we are ready to move to the next step).
- Experiment with alternative ways of presenting information: different audiences must receive the same message, based soundly on the safety case, but tailored to their ability and needs. The use of focus groups with randomly sampled members of the public may be helpful in terms of learning to more effectively communicate with the public.

- Be prepared, especially in a public meeting, if it appears to be the will of the audience, to forego addressing long-term safety and instead discuss more near term risks, such as those from construction, operation, or transportation (perhaps have another presentation, or even another presenter, at hand).
- Attempt to understand audience expectations.
- Practice, if possible, before a live, critical audience.
- Use figures, graphics, and illustrations of principles and suitable natural and anthropogenic analogues with simple self-contained messages.

B5. The presentation of a safety case

Persons familiar with the context, content and basis of the safety case must make the safety case presentations. ***For building confidence in a safety case, "**how it is said**" is as important as "**what is said**".*** In particular, confidence should not be *declared*. Rather, the content and approaches used in making the presentation should *demonstrate* why confidence is warranted.

Competence, openness, honesty and flexibility in the presenter keep an audience engaged and positive if they are inclined to be positive. Objectivity needs to be maintained, and advocacy should be limited to statements regarding the quality and integrity of the science and engineering that are the basis for the safety case. Advocacy must be of the form that says the presenter is convinced that the safety case is a reflection of honest inquiry, and good science and engineering. The balance between objectivity and advocacy can be achieved by freely disclosing uncertainties, the information needs implied by those uncertainties, and indicating that work is planned or in progress to obtain the information. As a programme matures, this may be called confirmatory evidence, but if this term is applied prematurely, it may be interpreted as a search for only evidence that is likely to be positive or confirmatory.

Safety case specialists need training in communication, and communications specialists need training in technical topics. Further, both technical staff and communications specialists are required at public meetings, because they have complementary skills that support the presentation of the safety case. Communications specialists can be particularly skilled at identifying and understanding the doubts and fears that are often expressed at public meetings. It is important that the concerns be acknowledged and discussed, and that means for addressing the concerns be identified.

By its nature, a safety case is an integration and abstraction of knowledge. Therefore, the assumptions, reasoned arguments, abstractions, data, models, and computer codes that underpin the IPA within a safety case must be shown to be reasonable and defensible for their intended use. Also, they must be traceable to sound science and good engineering practice, comprising:

- A site description based on extensive field investigations of the subsurface geological formation and the surface environment.
- A reference design derived from extensive laboratory investigations and conceptual engineering studies.
- A set of exposure scenarios selected through a broad-based, systematic and comprehensive treatment of relevant features, events and processes.
- Underlying numerical analyses of consequences, uncertainties and sensitivities using qualified methods, tools and procedures.

- Relevant natural and archeological analogue studies to show that the proponent has learned the lessons that nature has to offer
- Extensive peer review and regulatory oversight.

Although a safety case's IPA requires the application of technical and scientific rigor, its component models and the treatment of specific processes, especially in terms of the simplifications made, may not easily satisfy scientific or other technical specialists looking at details that are peculiar to their speciality. Some advice offered by such individuals may be scientifically correct and interesting, but may not be important to safety.

Generally, safety case specialists will need training in public communication to teach them how to avoid becoming defensive of their professional standing or judgement. Presenters must be open to criticism and answer questions without resorting to complex diagrams or explanations unsuited for some audiences. At the same time, it is not a good idea to put a safety case/IPA talk into the hands of public communication persons for delivery. Unfamiliarity with technical nuances embedded in a chart, graph or a safety case or IPA-specific section could lead to an inability to correctly answer questions.

Implementers may instill confidence in others by showing a range of arguments including (but not limited to) a suggestion of regulatory compliance, and being able to argue, to an extent appropriate for the maturity of the site and engineering work, that this gives assurance of safety. Regulators need to defend regulations, in terms of their adequacy for ensuring safety. ***The competence and independence of the regulator are crucial to the credibility of the implementer as well as the regulator.***

In developing documentation and preparing for the presentation of a safety case, it is apparent that a wide range of questions will arise and need to be answered. In particular, presenters need to be prepared to respond to "what-if" questions and concerns related to worst-case scenarios. However, presenters should avoid speculating in cases where the answer to the question is not known. Similarly, presenters should avoid discussing preliminary safety case/IPA findings that are not yet understood or have not yet been internally reviewed. Presenting complex results without fully understanding the reasons for the shapes of curves, for example, could lead to embarrassment if the audience asks pointed questions. Changing or contradicting an answer that was given at a previous meeting can be perceived as deceptive. On the other hand, saying that the answer is not yet known, but that evaluations and sensitivity studies are in process to determine the answer, is both honest and credible if true. This type of answer needs to be followed up with a commitment to provide an answer at a later date, and an arrangement to do so must be made.

Confidence has been discussed in some detail in this report. A recurring observation from those who have presented safety cases and their IPAs to various audiences is, however, that ***the concept of confidence means different things to different people***. This is true for people within the same audience, and varies greatly from audience to audience. It is a qualitative feeling of assurance. That feeling of assurance may be as difficult to obtain for an untrusting member of the public as it is for a technical specialist. In the case of the member of the public, it may be a matter of a lack of trust in the message or the messenger. In the case of the technical specialist, it may be a well-developed sense of what is scientifically sufficient that is not being met. Therefore, it may be wise to always express confidence, if one has confidence, as a personal conviction based on several lines of evidence, including IPA results as couched in the context of an overall safety case. It is important for the presenter to be able to honestly say he or she has confidence in the quality of the science and in the people that have contributed to the safety case.

Whether implementer or regulator, it is necessary to have a formal way of openly and honestly dealing with contrary technical opinions within one's own programme. If there is technical dissent within a programme, or if there are contrary technical opinions outside the programme, it is worthwhile discussing the different opinions in the safety case document, and to show how the differences have been evaluated and addressed. For example, a difference of opinion could be addressed in an uncertainty analysis, or through an alternate conceptual model. A presenter of a safety case is in a better position to respond to a question on a difference of opinion if that difference is explicitly addressed in the documentation of that safety case.

B6. Implications of communications

Effective communications are not one-way exchanges. Credibility can be damaged if it becomes apparent that what was advertised as an exchange, is in fact only a one-way presentation of information. As noted previously, it is important to allow stakeholders to reach their own conclusions and level of confidence by providing them with the relevant information, and responding to their questions and feedback.

Part of being credible in communications is being prepared to be reasonably flexible in terms of both design and work scope, where it is warranted and feasible. The audience will question the sincerity of the implementer's willingness to communicate in a two-way fashion if it becomes apparent that there is a lack of programmatic flexibility, and that the interactions will not have any impact on the safety case work or on other aspects of the repository programme.

All communications involving formal feedback from regulators and review or oversight groups should be documented. Less formal feedback, such as from a public meeting that is not a formal hearing, can be captured in meeting minutes that are made publicly available. Documentation is particularly needed when commitments are made, or when disagreement persists.

The presentation of a safety case is not an attempt to create converts or believers. It is an attempt to communicate the safety case and its basis. Communication is successful if a stakeholder, whether for or against a repository, comes away with a clearer understanding of the course of action recommended in the safety case and its basis. This basis includes the technical issues and risks involved, and also the processes for further developing the repository and its safety case, for stakeholder involvement, and for decision making.

Appendix C

THE IPAG-3 INITIATIVE AND ITS QUESTIONNAIRE ON APPROACHES AND ARGUMENTS USED TO ESTABLISH CONFIDENCE IN LONG-TERM SAFETY AND THE OVERALL RESULTS OF IPAs

C. FOCUS OF THE IPAG-3

In every national radioactive waste management programme, the safety case is paramount, and the focus of both the implementer's and regulator's activities.

"The safety case is a collection of arguments, at a given stage of repository development, in support of the long-term safety of the repository". The basis for a safety case[1] lies in science and engineering, and this is reflected in the detailed and rigorous modelling of the disposal system, as well as in semi-quantitative and qualitative arguments made to support long-term safety. In addition, the safety case must provide a statement of confidence in the overall assessment of long-term safety, and argue the adequacy of the present science, engineering, and modelling work *for the stage of repository development or function being addressed*. The statement of confidence should include an acknowledgement and discussion of uncertainties and unresolved issues, and provide a road map to the work being planned to resolve those issues (IPAG-1 report, and NEA "Confidence report").

The approaches and arguments used to establish and communicate confidence in long-term safety and in the overall results of Integrated Performance Assessments (IPAs) are the focus of Phase 3 of the Working Group on Integrated Performance Assessments of Deep Repositories (IPAG-3).

C1. PURPOSE AND DISTRIBUTION OF THE QUESTIONNAIRE

The *purpose* of the questionnaire is to collect information to prepare a progress report to RWMC and IGSC on the state of the art of obtaining, presenting and demonstrating confidence in long-term safety, and make recommendations on future directions and initiatives in the area of confidence building for the safety case.

The questionnaire is being circulated to persons nominated into the IGSC as well as to the representatives of both the former PAAG and SEDE groups. It is understood, however, that the IGSC nominee is responsible, eventually, for coordinating the responses to the questionnaire within his/her organization, and for having the completed questionnaire submitted to the NEA. Along with the submission of the responses to the questionnaires, the IGSC member should also indicate who – from his/her organization – would participate in the subsequent work of the IPAG. Namely, in the Spring 2000 meeting.

Answers are elicited from – and membership is limited to – the NEA Member organizations that have participated in the preparation or review of an IPA or an important IPA-related document, either in an implementer- or regulator-type capacity. As noted below, it is necessary that relevant source material exists and can be referenced.

---

[1] "Confidence in the Long-term Safety of Deep Geological Repositories – Its Development and Communication", NEA, 1999.

C2. INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE

Based on the experiences of organizations that tested an earlier draft of the questionnaire, it is expected that 2 to 3 person-days of effort will be required to complete the questionnaire. Some general instructions for completing the questionnaire are provided below.

C2.1 IPAs and other source material

It is acknowledged that, as source material, some organizations may want to refer to more than one IPA study or, alternatively, to relevant documents other than IPAs, e.g. major R&D programmes related to IPAs, or existing or contemplated regulations/guidelines concerning IPAs. The international peer reviews received by NEA and IAEA are also of interest. In any event, *the source material must be a document that can be referenced in the IPAG-3 report*. Thus, the source material must be either an existing document, or a document that will be published before the end of IPAG-3 (31 December 2000).

The actual selection of the source(s) of information is left to the judgement of each answering organization. The following guidance is provided for selecting source material for completing the questionnaire:

1. If multiple IPAs or related documents are available for the *same proposed repository*, the set of IPAs and IPA reviews for the proposed repository can be treated as one for the purposes of IPAG-3. The response to each question should be based on the most recent IPA and IPA review that contained information relevant to that question.
2. If an organization wishes to make reference to IPAs, IPA reviews or IPA-related documents for *more than one proposed repository*, the same source of information should be consistently used when answering a series of questions. This implies that several answers may be needed for the same question. In all cases, the IPA and IPA review being referenced should be clearly stated.

C2.2 Structure of the questionnaire and guidance on providing responses

The questions are organised around five main topics covered in Parts A through E of the questionnaire.

Part A of the questionnaire contains general questions on the approach to demonstrating confidence in the IPA you produced or reviewed. Questionnaire Parts B, C, D and E contain more specific questions on aspects of confidence building.

In responding to the questionnaire, please keep the following in mind:

1. The questionnaire should reflect the overall views and perspectives of your organization in an integrated fashion. Thus, there should be consultation with persons within your organization that are involved in other areas than your own, e.g., in site characterisation, engineering, safety assessment, etc.
2. Both regulators and implementers should attempt to answer all questions. Even if, in some cases, "what was done" questions may appear to be apply mostly to implementing organizations, regulators are asked to interpret these questions in terms of: (a) the extent to which explicit confidence statements made in the IPA affected the review and (b)

which information in the IPA, if any, was the most effective in making the regulator confident (or not confident) in the IPA.

3. “Yes” and “No” answers are not sufficient, as they do not provide a useful basis for preparing the IPAG-3 report. While the appropriate length of the response to each question is left to the discretion of the participating organizations, it is suggested that most responses should be between a paragraph to a half-page in length. If an organization wishes to provide more detailed information for some questions, it may be appropriate to provide the information in appendices to the main questionnaire responses.
4. Some of the questions may overlap, i.e.; portions of responses could be applicable to more than one question. If this occurs, the information can be presented once, and cross-referenced between responses. Please note, however, that unique and specific information is being requested in each question. Thus, please read the questions carefully, and try to address the nuances in each question.
5. In your answers, clearly differentiate between what was done in the IPA you produced or reviewed and any ideas that you have for modifications or improvements in the next IPA iteration. When referring to future work directions and needs for regulatory decision making, the focus should be on the next step in the repository development process. Please define what this next step is.

QUESTIONNAIRE

PART A – CASE STUDIES

1) Context of the IPA

a) What was the stage of repository development and goal of the IPA?

b) Who were the intended audiences?

2) Description of overall approach and individual arguments to evaluate or demonstrate confidence[2]

a) Briefly describe the overall approach used and individual arguments made to evaluate or demonstrate confidence in the IPA.

b) What was the information used to support the arguments? For example, to what extent is the support for the arguments found in the IPA calculations and to what extent is the support based on the qualitative aspects of the physical/chemical processes or engineered components of the disposal system?

c) Were the individual confidence arguments used systematically to produce an overall statement of confidence, or were the arguments separately reported and applied to specific aspects of the disposal system or performance assessment?

3) Communication of confidence arguments

a) Where were the arguments positioned within the IPA documentation (e.g. up front, throughout text, final conclusions)?

b) Were the arguments all published or were some used only to evaluate or build confidence internally in your organization?

c) Were any other presentational media used (e.g. brochures for general public, telling the "PA story" in word-pictures, electronic presentations etc.)?

4) Feedback on confidence arguments

a) Describe any feedback received on the effectiveness or effects of the confidence arguments from stakeholders.

b) Did the confidence arguments themselves raise any new issues with stakeholders? If so, what were they, and how were the issues addressed?

5) Retrospective assessment of the overall approach and arguments used to build confidence

a) Retrospectively, have you identified additional confidence arguments that could have been made in the IPA?

b) Were there additional arguments you would like to have made but could not (e.g. due to insufficient information)?

c) Could the IPA, repository design or site characterisation work have been better planned and executed in order to support confidence arguments?

---

[2] Please note that more detailed information is requested in Part B.

6) Activities to aid confidence building in future IPAs

a) Have you identified any specific activities to aid confidence building in future IPAs?

b) What are the most urgent requirements for conducting R&D and/or further developing confidence building approaches and arguments?

7) Other aspects which contributed to overall confidence

a) Were there any other aspects of the IPA or the regulatory review process, which contributed indirectly to overall confidence?

QUESTIONNAIRE

PART B – DEMONSTRATING THE ADEQUACY OF BARRIERS AND MULTI-BARRIER SYSTEMS

Background

Multiple barriers are required in most national regulations, and are viewed as an important concept for confidence building in most radioactive waste disposal programmes. The multi-barrier concept requires that each of several barriers (e.g. waste form, canister, buffer, geologic media) will contribute to safety and that the various safety functions of the barriers will provide a certain degree of redundancy with respect to isolation and/or retention of radionuclides. However, the barriers cannot be totally independent and redundant, as a deep geologic disposal facility consists of passive components, which act together in a complementary manner.

The IPAG-2 report noted that the existing definitions of the multi-barrier concept leave room for misinterpretation amongst specialists and by non-technical stakeholders. The difficulty in interpretation arises when the multi-barrier concept is confused with the "defense-in-depth" principle used in reactor safety. The defense-in-depth principle requires that multiple barriers should be completely independent and that there should be redundant barriers. This is possible in a reactor system, as reactors are actively controlled, and redundant and independent barriers can be engineered for the reactor environment. It is not possible in a repository system where evolution of the barriers over thousands of years needs to be considered.

As a result, the IPAG-2 report recommended that a definition for the multi-barrier concept should be developed that clearly states that full independence and redundancy are not necessary or possible, and that describes the concept in the context of what is achievable and necessary in a deep geological disposal system. The questions below are aimed at developing a definition for the multi-barrier concept.

Questions

1) Definition of a barrier and the multi-barrier concept

a) How do you define a barrier? For example, is it a physical component of the system, or can it also be a safety function (e.g.: a zone where the geochemistry limits radionuclide migration due to solubility limits)?

b) Was this definition of a barrier stated in the IPA? If not, why?

c) What is your definition for the multi-barrier concept?

d) Was this definition of the multi-barrier concept stated in the IPA? If not, why?

e) What are the purpose and minimum requirements for a multi-barrier system, and how are these met? For example, to what extent is redundancy required in a multi-barrier system?

2) Evaluating the adequacy of a multi-barrier system

a) Describe any specific assessments that were conducted to demonstrate the adequacy of the multi-barrier system in the IPA. For example, were any scenarios evaluated where a key barrier was less effective than expected, or where the barrier was damaged?

b) Describe any specific assessments where a barrier was considered to have failed. How was barrier failure defined?

QUESTIONNAIRE

PART C – SUPPORTING ARGUMENTS

1) Multiple lines of reasoning

a) Were multiple lines of reasoning used for demonstrating confidence in long-term safety? If not, why?

b) For each line of reasoning used, describe the nature of the arguments (qualitative/quantitative), their basis (IPA, site observation), nature (primary or in support of primary analyses), and the intended audience.

c) What were the overall conclusions of the arguments?

d) What were the resulting benefits from making the arguments?

e) In retrospect, were any of the arguments found to be of limited value? Was the use of these lines of reasoning detrimental in any way to making the overall safety case?

2) Natural analogues and/or paleohydrology

a) Were natural analogues and/or paleohydrology used for supporting arguments in the safety case (or considered in the review of the IPA)? If not, why?

b) Briefly describe the information and knowledge used, and how it was used to support the safety case.

c) In your opinion, what was the added value of the natural analogues and/or paleohydrology to the overall safety case?

3) Alternative performance and safety indicators

a) Were alternative performance and/or safety indicators used for demonstrating confidence in long-term safety? If not, why?

b) Describe each alternative indicator used, including how it was used to support overall safety, the time frames over which it was applied, and the extent to which it was possible to show satisfactory performance against the indicator.

c) Did all of the indicators assessed support long-term safety? If not, how was this addressed in the IPA?

4) Biosphere considerations

a) Briefly describe the arguments made regarding the adequacy of the representation of the biosphere in the IPA. In particular, how was the inherent uncertainty in the biosphere analysis factored into the IPA confidence statements.

b) In the IPA, is the biosphere considered to be a barrier or to have safety functions? If so, briefly describe the barrier or safety functions that are provided by the biosphere in the IPA.

QUESTIONNAIRE

PART D – DEMONSTRATING THE ROBUSTNESS OF THE SYSTEM OR COMPONENTS OF THE SYSTEM

Background

The NEA document on “Confidence in the Long-term Safety of Deep Geological Repositories – Its Development and Communication” defines and uses the concepts of intrinsic and engineered robustness.

> ***Engineered robustness****: “Intentional design provisions that improve performance with respect to safety, in order either to compensate for known phenomena and uncertainties or to guard against the possible consequences of undetermined phenomena, are said to provide "engineered robustness" (e.g. - conditioning the waste with more durable matrices, over-dimensioning of certain barriers, changing the lay-out of the facility, etc.).”*
>
> ***Intrinsic robustness****: “Intentional siting and design provisions that avoid detrimental phenomena and the sources of uncertainty through the incorporation of features that are simple, for which there is practical experience, and which are acted upon by processes that are well understood, are said to provide "intrinsic robustness" (the selection of a site and design that has the potential to provide long-term isolation, with features that are amenable to a credible performance assessment).”*

Questions

1) Application of these (or similar) concepts in preparing or reviewing an IPA

a) Briefly describe any concrete examples of the intrinsic robustness of the system concept considered in your programme, or in the IPA you reviewed. How was the information used?

b) Briefly describe any concrete examples of engineered robustness of the system concept considered in your programme, or in the IPA you reviewed. How was the information used?

c) Has the pursuit of an adequate level of robustness influenced the complexities in assessment models and the data acquisition needs?

d) How was robustness communicated?

QUESTIONNAIRE

PART E – BUILDING CONFIDENCE THROUGH ITERATIVE ASSESSMENT CYCLES

Background

The NEA Confidence Report (see previous question) states:

“*If, either following the safety assessment itself or following the compilation and presentation of a safety case, the evaluated confidence is found to be insufficient, then the assessment basis must be re-evaluated and modified with a view to confidence enhancement and a new assessment carried out. If, following the (repeated) compilation of a safety case, convergence to sufficient confidence is not achieved, then the decision sequence that drives repository development may need to be revised. The iterative process of confidence evaluation and enhancement may be viewed in terms of “confidence cycles”. The concept of confidence cycles reflects the current dynamic approach to achieving confidence, especially during the early stages of repository development, when information increases rapidly in quantity and quality*”.

Questions

1) Impacts of the assessment of the confidence level of the safety case

a) Briefly describe any examples where the assessment of the confidence level of the safety case in an IPA (performed or reviewed) has led to any of the following actions:

- reducing the commitment involved in progressing to the next iterative stage of the safety case development?
- changes in the strategy for building the safety case?
- request for additional site or experimental information?
- changes in repository design or siting?

2) Examples of the interplay between PA/SA and the technological development of the repository

a) What has mostly driven design changes in your programme (results of IPAs, re-assessment of engineering feasibility, something else)?

b) What has mostly driven site selection in your programme (results of IPAs, political constraints, something else)?

c) Briefly describe any examples where you have provided siting exclusion criteria or identified desirable site characteristics?

d) *Prior to selecting the site or repository concept*, were FEP lists used to guide the site selection and/or design process?

Appendix D

LIST OF MEMBERS AND ADDITIONAL PARTICIPANTS TO TORONTO MEETING

IPAG-3 MEMBERS AND ADDITIONAL PARTICIPANTS TO TORONTO MEETING

BELGIUM

Peter DE PRETER
NIRAS-ONDRAF
Avenue des Arts, 14
B-1210 Bruxelles
Tel: +32 2 2121049
Fax: +32 2 2185165
Eml: p.depreter@nirond.be

CANADA

Peter FLAVELLE
Wastes and Decommissioning Division
Canadian Nuclear Safety Commission
PO Box 1046, Station B
280 Slater Street
Ottawa, Canada K1P 5S9
Tel: +1 613 995-3816
Fax: +1 613 995-5086
Eml: flavellep@cnsc-ccsn.gc.ca

Paul GIERSZEWSKI
Nuclear Waste Management Division, H16 E26
Ontario Power Generation
700 University Ave
Toronto M5G IX6
Tel: +1 416 592-2346
Fax: +1 416 592-7336
Eml: paul.gierszewski@ opg.com

Mark JENSEN
Nuclear Waste Management Division, H16-E27
Ontario Power Generation
700 University Ave,
Toronto, Ontario, M5G 1X6
Tel: +1 416 592-8672
Fax: +1 416 592-7336
Eml: mark.jensen@opg.com

Doug METCALFE
Wastes and Decommissioning Division
Canadian Nuclear Safety Commission (CNSC)
PO Box 1046, Station B
280 Slater Street
Ottawa, Canada K1P 5S9
Tel: +1 613 995 5294
Fax: +1 613 995 5086
Eml: metcalfed@cnsc-ccsn.gc.ca

Sean RUSSELL
Nuclear Waste Management Division, H16 D27
Ontario Power Generation
700 University Ave,
Toronto, Ontario, M5G 1X6
Tel: +1 416 592-2854
Fax: +1 416 592-7336
Eml: sean.russell@opg.com

CZECH REPUBLIC

Soña KONOPASKOVA
Radioactive Waste Repository Authority
Dlazdena Street 6,
Praha 1
Tel: +420 214 21511
Fax: +420 2 24 907 600
Eml: Konopaskova@rawra.cz

FINLAND

Juhani VIRA
Manager, Posiva Oy
Töölönkatu 4
FIN-00100 HELSINKI
Tel: +358 9 2280 3740
Fax: +358 9 2280 3719
Eml: juhani.vira@posiva.fi

FRANCE

Gérald OUZOUNIAN
ANDRA
Parc de la Croix Blanche
1-7, rue Jean-Monnet
F-92298 Chatenay-Malabry CEDEX
Tel: +33 1 46 11 83 90
Fax: +33 1 46 11 84 10
Eml: gerald.ouzounian@andra.fr

Sylvie VOINIS (Presently at the NEA)
ANDRA
Parc de la Croix Blanche
1-7 rue Jean-Monnet
F-92298 Chatenay-Malabry Cedex
Tel: +33 1 46 11 81 10
Fax: +33 1 46 11 80 13
Eml: sylvie.voinis@andra.fr

GERMANY

Bruno BALTES
Gesellschaft für Anlagen-und
Reaktorsich GRS) mbH
Schwertnergasse 1
D-50667 Köln
Tel: +49 221 2068 795
Fax: +49 221 2068 939
Eml: bb@grs.de

Dieter BUHMANN
Gesellshaft für Anlagen-und
Reaktorsichereit (GRS) mbH
Theodor-Heuss-Strasse 4
Postfach 2126
D-38011 Braunschweig
Tel: +49 531 801 2207
Fax: +49 531 801 2200
Eml: buh@grs.de

Klaus-Juergen ROEHLIG
Gesellschaft für Anlagen- und
Reaktorsicherheit (GRS) mbH
Schwertnergasse 1
D-50667 Köln
Tel: +49 221 2068 796
Fax: +49 221 2068 939
Eml: rkj@grs.de

Jürgen WOLLRATH
Bundesamt für Strahlenschutz BfS
Postfach 10 01 49
D-38201 Salzgitter
Tel: +49 5341 885 642
Fax: +49 5341 885 605
Eml: JWollrath@BfS.de

JAPAN

Hiroyuki UMEKI
Geological Isolation Research Project Group
Nuclear Cycle Backend Division
Japan Nuclear Cycle Development Institute
NKK Bldg, 1-1-2, Maruno-uchi
Chiyoda-ku, Tokyo 100-8245
Tel: +81 3 5220 3316
Fax: +81 3 5220 3372
Eml: umeki@hq.jnc.go.jp

SPAIN

Jesus ALONSO
ENRESA
Calle Emilio Vargas, 7
E-28043 Madrid
Tel: +34 91 566 8108
Fax: +34 91 566 8165
Eml: jald@enresa.es

SWEDEN

Allan HEDIN
Swedish Nuclear Fuel
& Waste Management Co. (SKB)
Box 5864
S-102 40 Stockholm
Tel: +46 8 459 85 84
Fax: +46 8 661 57 19
Eml: allan.hedin@skb.se

Bo STROMBERG
Office of Nuclear Waste
Swedish Nuclear Power Inspectorate (SKI)
S-10658 Stockholm
Tel: +46 8 698 8485
Fax: +46 8 661 9086
Eml: bo.stromberg@ski.se

SWITZERLAND

Johannes O. VIGFUSSON
Section for Transport and Waste Management
HSK-Swiss Federal Nuclear Safety Inspectorate
CH-5232 Villigen HSK
Tel: +41 56 310 3974
Fax: +41 56 310 3907
Eml: johannes.vigfusson@hsk.psi.ch

Piet ZUIDEMA
NAGRA
Hardstrasse 73
CH-5430 Wettingen
Tel: +41 56 437 12 87
Fax: +41 56 437 12 07
Eml: zuidema@nagra.ch

UNITED KINGDOM

Lucy BAILEY
UK Nirex Ltd
Curie Avenue
Harwell, Didcot
Oxfordshire OX11 ORH
Tel: +44 1235 825357
Fax: +44 1235 820560
Eml: lucy.bailey@nirex.co.uk

Linda CLEMENTS
British Nuclear Fuels (BNFL)
Environmental Modelling
R002 Rutherford House
Risley, Warrington, WA3 6AS
Tel: +44 1925 832 048
Fax: +44 1925 832 016
Eml: linda.m.clements@bnfl.com

Eugene Kelly
BNFL
Environmental Risk Assessments
Sellafield,Seascale,
Cumbria CA20 1 PG
Tel: +44 1946 779169
Fax: +44 1946 779348
E-mail: ejk2@bnfl.com

Trevor SUMERLING
Safety Assessment Mngt. Ltd
Beech Tree House
Hardwick Road
Whitchurch-on-Thames
READING, RG8 7HW
Tel: +44 1189 844 410
Fax: +44 1189 841 440
Eml: trevor@sam-ltd.demon.co.uk

Roger YEARSLEY
Room 6.02
Environment Agency
Steel House
11 Tothill Street
London SW1H 9NF
Tel: +44 20 7664 6833
Fax: +44 20 7664 6836
Eml: roger.yearsley@ environment-agency.gov.uk

UNITED STATES OF AMERICA

Richard CODELL
U.S. Nuclear Regulatory Commission
Mail Stop T7D13
WASHINGTON, DC 20555
Tel: +1 301 415 8167
Fax: +1 301 415 5399
Eml: rbc@nrc.gov

Mark NUTT
U.S. Department of Energy
Yucca Mountain Site Characterization
Office, M/S 523
1551 Hillshire Drive
Las Vegas, NV 89134
Tel: +1 702 794-1424
Fax: +1 702 794-1435
Eml: mark_nutt@notes.ymp.gov

Abraham E. VAN LUIK
U.S. Department of Energy
Yucca Mountain Site Characterization
Office, M/S 523
1551 Hillshire Drive
Las Vegas, NV 89134
Tel: +1 702 794-1424
Fax: +1 702 794-1435
Eml: abe_vanluik@ymp.gov

Eric ZWAHLEN
U.S. Department of Energy
Yucca Mountain Site Characterisation
Office, M/S 523
1551 Hillshire Drive
Las Vegas, NV 89134
Tel: +1 702 794-1424
Fax: +1 702 794-1435
Eml: eric_zwahlen@notes.ymp.gov

OECD Nuclear Energy Agency

Claudio PESCATORE
OECD Nuclear Energy Agency
Radiation Protection
and Waste Management Division
12, boulevard des Iles
F-92130 Issy-les-Moulineaux (France)
Tel: +33 1 45 24 10 48
Fax: +33 1 45 24 11 10
Eml: pescatore@nea.fr

Johan ANDERSSON
(Consultant to the NEA)
JA Streamflow AB
Korta Gatan 7
S-171 54 Solna (Sweden)
Tel: +46 70 622 21 32
Fax: +46 8 562 00 350
Eml: johan.andersson@streamflow.se

CHINESE TAIPEI

Observer

Wen-Shou CHUANG,
Institute Of Nuclear Energy Research Road
INER
Village, Lungta, 1000, Wenhua Road,
Lung-Tan
Taoyuan, Taiwan, 325
Republic of China
Tel: +886 2 23651717 x5634
Fax: +886 3 4711411
Eml: wschuang@iner.aec.gov.tw

ACRONYMS

EIS:	Environmental Impact Statement
FEPs:	Features, Events and Processes
FSC:	Forum on Stakeholders Confidence
IGSC:	Integration Group for the Safety Case
EIP(s):	Integrated Performance Assessment(s)
IPAG:	Working Group on Integrated Performance Assessments of Deep Repositories
PA:	Performance Assessment
PAAG:	Performance Assessment Advisory Group
RWMC:	Radioactive Waste Management Committee
SEDE:	Site Evaluation and Design of Experiments Co-ordinating Group

VERSION FRANÇAISE

EXPOSÉ DE SYNTHÈSE

Le Groupe consultatif de l’AEN sur l’évaluation des performances des systèmes d’évacuation des déchets radioactifs (PAAG)[1] a établi en 1994 un Groupe de travail sur les évaluations intégrées des performances des dépôts profonds (IPAG) ayant pour mission générale d’offrir un cadre privilégié pour débattre sur la sûreté et l’évaluation des performances (PA), de procéder à un examen de l’état d’avancement général des dossiers de sûreté et des études d’évaluation intégrée des performances (EIP). Ces travaux ont été exécutés en plusieurs phases, la composition et les tâches du groupe pouvant changer d’une phase à une autre.

Au cours de la première phase [AEN, 1997], l’objectif était d’examiner les évaluations des plus récentes susceptibles de fournir une indication de l’état actuel de l’évaluation des performances et permettant de se faire une idée sur ce qui pourrait être fait lors d’études futures. Au cours de la deuxième phase [AEN, 2000-a], l’objectif visé était d’analyser l’expérience des examens par des pairs sur les évaluations intégrées des performances (EIP), et plus particulièrement des revues en appui à l’évaluation réglementaire, du point de vue tant des autorités de sûreté que des exploitants.

La troisième série de travaux, dénommée IPAG-3, est décrite dans le présent rapport. L’IPAG-3 a été exécuté principalement de juin 1999 à novembre 2000.

Le groupe a évalué les méthodes et arguments qui ont été utilisés pour instaurer et communiquer la confiance dans la sûreté et les résultats globaux des EIP. L’IPAG-3 avait pour objectif d’évaluer l’état actuel de moyens permettant de gagner, de communiquer et de démontrer la confiance dans la sûreté à long terme, et de formuler des recommandations sur les orientations et initiatives futures en vue d’améliorer la confiance. Vingt organisations nationales ont participé à la Phase 3 ; chacune ayant soit exécuté, soit analysé une EIP ou un dossier de sûreté récent. Comme dans les phases précédentes, un questionnaire a été utilisé pour structurer les débats.

Le corps du document décrit les conclusions de l’IPAG-3 s’agissant (i) de préparer la voie à l’argumentation en vue de gagner la confiance et (ii) de développer et de documenter les arguments pour gagner la confiance. Le rapport présente aussi certaines considérations finales notamment une comparaison des conclusions de l’IPAG-3 avec celles des phases antérieures et d’autres activités entreprises par l’AEN [AEN, 1999]. On trouvera dans les annexes au présent rapport le questionnaire de l’IPAG-3 ainsi qu’une compilation des réponses à ce dernier. Les observations et recommandations de l’IPAG-3 sont récapitulées ci-après. Lorsque des recommandations sont formulées, elles s’adressent au premier chef aux organisations procédant à l’exécution ou à l’examen des dossiers de sûreté et des évaluations intégrées de performance.

L’aménagement d’un dépôt géologique profond se caractérise par plusieurs étapes s’inscrivant dans un processus par étapes et progressif qui, globalement, exige plusieurs décennies pour être mené à terme. La durée pouvant été longue de ce processus reflète la nouveauté et la

---

1. Le PAAG et le SEDE ont été remplacés par le Groupe d'intégration pour le dossier de sûreté (IGSC) en 2000.

complexité des tâches liées à l'élaboration d'un concept de dépôt de même que le caractère sensible de tels projets pour la société, et le désir d'avancer à pas mesurés eu égard aux aspects techniques et à l'acceptabilité sociale. À la fin de chaque étape du processus décisionnel, une décision est prise sur le point de savoir s'il convient de poursuivre et si les prescriptions visant l'étape suivante d'aménagement ont besoin d'être révisées. Il importe à chaque étape du processus d'aménagement, de communiquer le fondement du niveau actuel de confiance, et d'indiquer clairement la stratégie à suivre pour résoudre les problèmes en suspens.

D'une façon générale, le « dossier de sûreté » est l'une des bases essentielles permettant de prendre des décisions relatives à l'aménagement des dépôts géologiques. D'après le document de l'AEN sur la confiance *Confidence in the Long Term Safety of Deep Geological Repositories, AEN, 1999*, le dossier de sûreté est un ensemble d'arguments formulés, à une étape donnée de l'aménagement du dépôt, pour appuyer la confiance dans la sûreté à long terme de ce dépôt. Un dossier de sûreté comprend les conclusions d'une évaluation de la sûreté et une déclaration de la confiance dans ces conclusions. Il doit présenter l'existence de problèmes non résolus et fournir des orientations visant les travaux à mener pour résoudre ces problèmes au cours des étapes futures. Des analyses détaillées des performances à long terme du dépôt, sous la forme modèles de calculs, sont normalement présentées dans une EIP et constituent le cœur du dossier de sûreté. Il convient d'indiquer dans le dossier de sûreté sa finalité, de l'argumenter et de l'étayer convenablement, et de le replacer dans son contexte en identifiant la manière dont il contribue au processus de décision.

Il faut des arguments pour construire la confiance tant dans la sûreté intrinsèque du système d'évacuation que dans l'évaluation des performances à long terme de ce système. Il convient de recourir à une variété d'arguments visant à contribuer, à instaurer et à communiquer cette confiance aussi bien aux experts chargés de l'examen technique qu'aux autres parties prenantes. Les arguments essentiels, recensés dans l'IPAG-3, sont exposés dans le chapitre 3 du présent rapport et sont récapitulés dans le tableau ci-après.

Catégorie	Arguments
Confiance dans le système d'évacuation proposé	• Robustesse intrinsèque du système à barrières multiples. • « What if? »scénarios envisagés et calculs de simulation. • Comparaison avec des exemples familiers et des analogues naturels.
Confiance dans les données et la connaissance du système d'évacuation	• Qualité du programme de recherche et des études de site. • Procédures d'assurance de la qualité. • Données provenant d'une variété de sources et de méthodes d'acquisition. • Utilisation de techniques formelles de suivi des données.
Confiance dans la méthode d'évaluation	• Méthode d'évaluation logique, claire et systématique. • Évaluation exécutée dans un cadre auditable vérifiable. • Construction de la compréhension à travers une approche itérative. • Revue d'experts indépendants sur l'approche adoptée.

Catégorie	Arguments
Confiance dans les modèles d’évaluations	• Explication de la raison pour laquelle les résultats sont intuitifs. • Prise en considération d’autres modèles conceptuels et méthodes de modélisation – simples et complexes. • Vérification des modèles par rapport aux expériences et à des observations de la nature. • Exercices de comparaisons de modèles. • Comparaison avec les analogues naturels. • Éléments de preuve indépendants, par exemple informations paléohydrogéologiques.
Confiance dans le dossier de sûreté et les analyses d’EIP	• Exposés clairs et justifications des hypothèses. • Démonstration du fait que les hypothèses sont représentatives ou empreintes de conservatisme. • Études de sensibilité. • Stratégies claires de gestion et de traitement des incertitudes. • Indicateurs potentiels de sûreté. • Types d’arguments multiples.
Confiance par le biais du retour d’information vers la conception et la caractérisa-tion du site	• Appui pour les éventuelles modifications apportées à la conception de la formule d’évacuation. • Qualité et sûreté globales du système d’évacuation.

Tous les systèmes d’évacuation représentés dans le cadre de l’étude de l’IPAG ont en commun un système à barrières multiples, dont la définition exacte peut toutefois varier d’un pays à un autre. L’IPAG-3 a recommandé aux exploitants de définir clairement dans leur dossier de sûreté le sens à donner au concept barrières multiples, notamment les éventuelles exigences fonctionnelles en matière de sûreté à long terme. D’ordinaire, les évaluations du caractère suffisant du système à barrières multiples proposé occupent une place prépondérante dans une EIP.

Au niveau le plus élevé, la principale gageure, dans le cas de tout dossier de sûreté et de l’EIP associée, est de traiter les inévitables incertitudes résultant des longues échelles de temps mises en jeu. Dans une évaluation de performance, il est nécessaire de traiter de telles incertitudes d’une manière exhaustive et de montrer que, sur la base des données et informations disponibles et compte tenu de ces incertitudes, on peut escompter que le dépôt assure la protection à long terme de l’homme et de l’environnement.

La confiance dans les données utilisées dans le dossier de sûreté se fonde sur l’assurance que les travaux de recherche et de caractérisation du site ont été convenablement exécutés et que les données ont été correctement comprises et interprétées dans l’évaluation des performances. Il convient donc de mettre en place un système approprié de contrôle de la qualité permettant de suivre les données de leur source à leur utilisation dans le dossier de sûreté. La méthode d’évaluation constitue également un élément clé du dossier de sûreté et doit être claire et transparente. L’IPAG-3 recommande que les hypothèses fondamentales et leurs justifications soient clairement énoncées dans une section spécialement conçue à cet effet du dossier de sûreté. Cette dernière devrait indiquer clairement la base de la confiance dans les modèles utilisés et les résultats obtenus. En particulier, il est nécessaire d’une part d’évaluer et analyse la sensibilité de la sûreté et des performances du système aux incertitudes entachant les données, les modèles et le scénarios, et d'expliquer d'autre part la raison pour laquelle les résultats vaut servir à la prise de décision.

L'IPAG-3 recommande d'inclure dans le dossier de sûreté une « déclaration de confiance » clairement explicitée, comme cela était proposé dans NEA [1999], et de la faire figurer en bonne place dans la documentation. Une telle déclaration pourrait, par exemple, s'appuyer sur un examen de la méthode de gestion et de traitement des incertitudes, mentionnant les principales hypothèses empreintes de conservatisme et leurs incidences, et mettant en lumière les éventuelles « marges de sûreté », telles que des caractéristiques ou processus « positifs » qui n'ont pas été inclus dans les analyses. La déclaration de confiance devrait expliciter clairement la manière dont les résultats se situent par rapport aux critères réglementaires pertinents, et elle pourrait aussi établir des comparaisons avec les niveaux de rayonnements présents dans la nature et d'autres risques de la vie quotidienne, afin de situer dans leur contexte les risques radiologiques imputables au dépôt.

Globalement, il ressort de l'expérience acquise par l'IPAG-3 et de celle résultant de travaux antérieurs, une nette tendance des programmes à avoir pour objectif une stratégie globale afin de gagner et de communiquer la confiance. La poursuite de la mise au point de ces stratégies en vue de gérer les incertitudes et de susciter la confiance dans la sûreté à long terme, constituera un volet important des travaux à mener par le Groupe d'intégration pour le dossier de sûreté. Des enseignements pratiques seront tirés des examens des dossiers de sûreté et des EIP en cours et futurs.

1. INTRODUCTION

Dans de nombreux pays Membres de l’OCDE, les agences de gestion des déchets et les autorités de sûreté prennent part à l’étude et à la solution des problèmes liés à la sûreté à long terme des dépôts souterrains destinés aux déchets radioactifs. Dans chaque programme national de gestion des déchets radioactifs, le dossier de sûreté est au centre des activités tant de l’exploitant que de l’autorité de sûreté. La sûreté doit être démontrée de manière à convaincre les agences de gestion des déchets, les autorités réglementaires, la communauté scientifique et technique plus large, les décideurs au plan politique et le grand public. En particulier, il faut des arguments convaincants capables de susciter au sein de ces groupes la confiance dans la sûreté des dépôts proposés, compte tenu des incertitudes qui entachent inévitablement la prévision à long terme du comportement de systèmes complexes, naturels et artificiels.

Le dossier de sûreté représente l’intégration, à un stade donné de l’aménagement du dépôt, d’arguments formulés pour appuyer la confiance dans la sûreté à long terme de ce dépôt [AEN, 1999]. Il devrait comporter une déclaration de confiance dans l’évaluation d’ensemble de la sûreté à long terme, et faire valoir le caractère adéquat des travaux en cours dans le domaine de la science, de l’ingénierie et de la modélisation vis à vis l’étape de développement du dépôt ou de la fonction considérés. Il devrait également inclure une reconnaissance et un examen des incertitudes et des problèmes non résolus et comporter un « planning » des travaux futurs à mener en vue de résoudre ces problèmes.

Un dossier de sûreté se fonde sur la science et l’ingénierie, ce qui se traduit pour une modélisation détaillée et rigoureuse en vue d’évaluer les performances à long terme du système. Le document technique fondamental sur lequel s’appuie le dossier de sûreté est habituellement appelé une Évaluation Intégrée des Performances (EIP). Celle-ci présente et commente la modélisation et les analyses effectuées, les mesures et de sûreté et des performances à long terme, et les incertitudes entachant ces mesures de la sûreté et des performances. Le dossier de sûreté situe alors dans leur contexte les résultats de l’évaluation des performances conjointement avec d’autres facteurs et considérations intéressant la décision sur le point d’être prise, tels que la réglementation pertinente, des arguments qualitatifs fondés sur des enseignements tirés de la nature, des informations provenant de l’expérience acquise en matière d’ingénierie et de matériaux et l’ensemble du processus de décision.

À ce jour, plusieurs dossiers de sûreté et EIP ont été menés et examinés au plan tant national qu’international. Ces documents et les examens connexes peuvent être évalués en vue d’en tirer des enseignements pour la préparation, la présentation et l’examen des dossiers. Les points communs dénotent des domaines de consensus, alors que les différences peuvent servir à mettre en lumière des aspects qui appellent un complément de réflexion et d’amélioration. En 1994, le Comité de la gestion des déchets radioactifs (RWMC) de l’AEN et son Groupe consultatif sur l'évaluation des performances des systèmes d'évacuation des déchets radioactifs (PAAG) ont établi le Groupe de travail sur les évaluations intégrées des performances des dépôts profonds (IPAG) afin de servir de cadre privilégié pour des débats éclairés sur les questions liées à l’établissement, la présentation et l’examen des dossiers de sûreté et des EIPs. Les résultats des deux premières phases de l’IPAG (IPAG-1 et IPAG-2) ont été publiés auparavant [NEA 1997 et 2000-a] et le présent rapport rend compte des résultats de la troisième phase de l’IPAG (IPAG-3).

Lorsque l’IPAG a été établi et au cours des Phases 1 et 2, les expressions « dossier de sûreté » et « EIP » n’étaient pas clairement distinguées. L’expression « EIP » était utilisée pour décrire l’ensemble du dossier de sûreté aussi bien que le document technique sous-jacent qui présentait les évaluations des performances à long terme du dépôt. De ce fait, le paragraphe suivant qui récapitule l’IPAG-1 et l’IPAG-2, ne se réfère qu’aux seules « EIPs ». Dans le présent rapport cependant, comme suite au document de l’AEN sur la confiance [AEN, 1999], on a établi une distinction entre un « dossier de sûreté » et une « évaluation intégrées de performances » comme cela est indiqué plus haut.

Au cours de l’IPAG-1, des évaluations des performances provenant de dix organisations nationales ont été examinées afin de déterminer leur état au moment de l’exercice de l’évaluation des performances et de mette en lumière ce qui pourrait être fait dans le futur.. En ce qui concerne l’IPAG-2, l’objectif visé était d’examiner l’expérience acquise par suite de l’examen réglementaire des évaluations, du point de vue tant de l’exploitant que de l’autorité de sûreté. En particulier, l’IPAG-2 a été centrée sur les méthodes utilisées pour analyser les évaluations, les façons dont leur examens sont présentés et interprétés, l’expérience acquise tant par les autorités de sûreté que par les exploitants au cours du processus d’examen réglementaire, et les opinions sur les orientations et modifications qu’il faut apporter à l’avenir au processus de décision sur le plan réglementaire. La Phase 2 a bénéficié de la participation de 17 organisations nationales, chacune d’entre elles ayant soit exécuté, soit examiné une évaluation de performances.

Plusieurs agences de gestion des déchets et organisations réglementaires se rapprochent maintenant d’une phase où elles peuvent être appelées à prendre et à expliquer des décisions en matière de programmes et d’autorisations. Les actions des agences de gestion des déchets comme des organisations réglementaires sont susceptibles de faire l’objet d’un examen public et politique minutieux. S’agissant de la troisième phase de l’IPAG, le RWMC et le PAAG ont alors décidé que le moment était venu d’évaluer les méthodes et les arguments qui ont été utilisés pour asseoir et communiquer la confiance dans la sûreté et les résultats globaux des évaluations des performances. L’IPAG-3 avait pour objectifs d’évaluer l’état actuel des techniques permettant de communiquer et de gagner la confiance dans la sûreté à long terme, et de formuler des recommandations visant les orientations et initiatives futures en vue de l’améliorer. Les travaux relatifs à l’IPAG-3 ont été menés de juin 1999 à novembre 2000 sous la présidence de D. Metcalfe (CCSN, Canada) et de la façon suivante :

- Participation des autorités de sûreté et des exploitants, qui possédaient une expérience de l’établissement ou de l’examen de dossiers de sûreté et d’EIP.
- Informations recueillies à l’aide d’un questionnaire diffusé à toutes les agences de gestion des déchets représentées au sein du PAAG et du Groupe de coordination sur l'évaluation des sites et la conception des expériences pour l'évacuation des déchets radioactifs (SEDE). Ce questionnaire avait été testé auparavant par un groupe restreint d’agences. Dans la version finale du questionnaire, les informations qui avaient été demandées sur les méthodes et arguments qui avaient été utilisés pour asseoir et communiquer la confiance dans la sûreté, et les opinions relatives aux orientations et modifications qu’il faut apporter à l’avenir au processus de décision.

Tableau 1. **Organisations ayant contribué à l’IPAG-3**
Stade d’avancement et objet du dossier de sûreté ou de l’EIP

Organisation	Stade d’avancement	Documents de référence et/ou objet de l’évaluation
ANDRA, France	Demandes d’autorisation d’exploitation relatives à des laboratoires souterrains de recherches (LS) (un site dans de l’argile à Bure et un site dans du granite à déterminer).	Base pour la sélection des options initiales en matière de conception et des concepts préliminaires (Hoorelbecke et col., 1998) ; approche de la sûreté (Voinis et col., 1999) ; scénarios (Pierlot et col., 1997) ; description des modèles (Ben Slimane et col., 1999) ; choix de la conception (Ben Slimane et col., 1999).
AECB, Canada (remplacée par la CCSN en juin 2000)	Demande d’autorisation de la construction d’une voûte d’isolement à faible profondeur aux Laboratoires de Chalk River pour des déchets solides à vie courte (500 ans).	Le dossier de sûreté (AECB, 1996) avait pour objet d’obtenir une autorisation de construction. Dans sa réponse, la AECB a cerné les problèmes devant être traités avant qu'une autorisation de construction puisse être accordée (Metcalfe, 1999).
BNFL, Royaume-Uni	Un Dossier de Sûreté relatif à la phase après fermeture (DSAF) a été établi pour l’installation d’évacuation à faible profondeur de déchets de faible activité de Drigg, en Cumbria, Royaume-Uni. Un DSAF devra être fourni en septembre 2002 en vue de l’autorisation relative à la poursuite des opérations d’évacuation.	En vue de l’établissement du DSAF, BFNL a publié un rapport sur l’état d’avancement du DSAF de 2002 relatif à Drigg *[Status Report on the Development of the 2002 Drigg PCSC]* (BNFL, 2000). Il fournit une description détaillée de la méthode envisagée par BNFL pour l’évaluation de la sûreté radiologique de 2002. BNFL (2000).
BfS, Allemagne	Projet de dépôt KONRAD dans une mine de fer abandonnée.	À l’appui de la demande d’autorisation relative au projet de dépôt KONRAD. BfS (1990).
ENRESA, Espagne	Mise au point du concept. EIP relative à un dépôt dans une formation générique de granite.	Optimiser et comparer des modèles conceptuels d’installation, afin d’obtenir des données d’entrée pour le programme de sélection des sites et orienter les travaux de R&D. ENRESA (2000).

Organisation	Stade d'avancement	Documents de référence et/ou objet de l'évaluation
GRS-B, Allemagne	Le dépôt de Morsleben est une installation existante, mais la poursuite de son exploitation se limite aux mesures en vue de sa fermeture définitive.	Élaborer des stratégies en vue de la fermeture définitive du dépôt dans des conditions sûres et de démontrer la sûreté par une analyse à long terme. Storck et col. (2000)
GRS-K, Allemagne	Projet de dépôt KONRAD destiné à l'évacuation de déchets radioactifs peu calogènes.	Des experts de l'autorité chargée de délivrer les autorisations ont établi une opinion d'experts visant les évaluations de la sûreté, par un examen des documents relatifs à l'autorisation (en l'occurrence l'EIP) soumis par le requérant et en établissant leur propre EIP. NMU (1997).
HSK, Suisse	Études régionales en vue d'un dépôt de déchets de haute et moyenne activité. Pas de site envisagé, mais existence de données obtenues sur le terrain.	Voir NAGRA. Un examen en bonne et due forme exécuté par l'autorité de sûreté sera nécessaire lors de la sélection d'un milieu récepteur. Examen de la NAGRA (1994).
JNC, Japon	Travaux génériques de R-D et évaluation de la faisabilité.	Démontrer la fiabilité technique et le caractère adéquat des techniques et des données d'expérience en vue de construire un dépôt. Base permettant de choisir des sites et de formuler des règlements. JNC (2000).
NAGRA/EDRA, Suisse	Voir HSK. L'EIPs relative à Kristallin-I a marqué la fin de la phase d'étude régionale pour l'option dans des formations cristallines.	Réévaluer le milieu récepteur. Améliorer les connaissances. Déterminer les caractéristiques essentielles et les fourchettes des paramètres afin d'orienter la sélection de sites. Élaborer et tester la méthodologie d'évaluation de la sûreté. NAGRA (1994).
UK Nirex Ltd.	Mettre au point un concept générique d'évacuation (non spécifique à un site donné).	Définir une méthode permettant d'évaluer les performances après fermeture en présentant une description générale des importants facteurs qui déterminent les performances des dépôts, illustrés par l'application à dix milieux génériques. Bailey et Littleboy (2000).

Organisation	Stade d’avancement	Documents de référence et/ou objet de l’évaluation
ONDRAF/NIRAS, Belgique	État des techniques visant la faisabilité et la sûreté de l’évacuation en profondeur de déchets de haute activité à vie longue évalué tous les dix ans.	Obtenir la décision de poursuivre le programme de manière à passer à la phase finale des travaux de R et D et de lancer vers 2010 l’établissement d’un rapport préliminaire de sûreté. SAFIR-2 (à paraître en 2001), de Preter et col. (1999)
OPG, Canada	Le concept visant l’évacuation des déchets de combustible nucléaire du Canada doit être accepté avant d’entreprendre la sélection des sites.	Étayer l’énoncé des incidences environnementales. Aider à évaluer la formule utilisée pour l’évacuation du combustible dans un site hypothétique, à l’aide d’informations obtenues en surface et à partir de sondages. Les EIP constituant la base des réponses fournies par l’OPG sont les rapports de Goodwin et col. (1994) et de Goodwin et col. (1996) L’EIP d’ensemble est celle établie par l’AECL (1994a, b).
Posiva, Finlande	Décision de principe visant la nécessité d’un projet d’installation d’évacuation du combustible nucléaire irradié. Sélection d’un site en vue de la poursuite des études d’aménagement.	Étayer la déclaration d’incidence sur l’environnement de Posiva et la demande de décision de principe relative à une installation d’évacuation du combustible nucléaire irradié. Vieno et Nordman (1999), examen dans Ruokola dir. publ. (2000)
RAWRA, République tchèque	Étape préliminaire de l’aménagement d’un dépôt.	Montrer la fonction du dépôt et évaluer la sensibilité du système eu égard aux données d’entrée. (RAWRA, 1999)
SKB, Suède	Passage des études de faisabilité aux recherches relatives aux sites (sondages) dans au moins deux communes.	Étayer le passage à la phase des recherches relatives aux sites. Démontrer la faisabilité du concept KBS-3 en Suède. Démontrer les possibilités offertes par l’EIP. SKB (1999).
SKI, Suède	En 1988, la SKB a obtenu une autorisation restreinte d’exploitation pour le dépôt SFR destiné aux déchets d’exploitation.	L’EIP examinée avait pour objet d’obtenir une autorisation de déposer les déchets d’exploitation ayant la plus forte teneur en radionucléides dans un grand silo qui avait déjà été construit. Examen de la SKB (1987) dans SKI (1988) et de la SKB (1991) dans SKI (1992).

Organisation	Stade d'avancement	Documents de référence et/ou objet de l'évaluation
UKAEA, Royaume-Uni	Guide relatif aux exigences en matière d'autorisation.	Aucune évaluation relative à l'évacuation en profondeur n'est en cours d'examen. Les réponses se fondent sur UKAEA (1997) de même que sur Duerden et col. (1996), Yearsley et Sumerling (1998) et Sumerling (1999).
USDOE, États-Unis	Yucca Mountain est le site choisi pour faire l'objet de recherches. La prochaine étape consistera à formuler une recommandation relative au site.	TSPA[2] VA (DOE, 1998) porte sur la raison d'être de l'aménagement du dépôt à Yucca Mountain, et sur le fait que ce programme est susceptible de remplir ses objectifs en matière de sûreté de l'évacuation. Pas d'incidences réglementaires. Les documents supplémentaires utilisés pour préparer les réponses sont DOE (1999) et OCRWM (2000).
USNRC, États-Unis	La NRC des États-Unis se prépare à procéder en 2002 à l'examen d'une demande d'autorisation.	Affiner l'outil primordial d'examen de la NRC. Utiliser les analyses de sensibilité pour déterminer les aspects importants en matière de sûreté du système en indiquant où l'attention doit se porter en priorité au cours de l'examen. NRC (1999).

- Vingt organisations appartenant à douze pays, représentant aussi bien des agences de gestion des déchets que des autorités de sûreté, ont répondu au questionnaire comme cela est récapitulé au tableau 1[3]. Ce tableau précise aussi le stade d'avancement du programme de chaque organisation et les données concrètes ayant servi de base à leur contribution au questionnaire de l'IPAG-3.
- Les réponses au questionnaire ont été analysées en vue d'établir une compilation des divers arguments et méthodes qui ont été utilisés pour asseoir la confiance dans la sûreté à long terme de l'évacuation dans des formations géologiques profondes, et d'évaluer l'état actuel des moyens permettant de gagner, d'exposer et de démontrer la confiance dans la sûreté. Les réponses au questionnaire sont structurées dans un document appelé ci-après « la compilation », qui figure à l'annexe A au présent rapport.
- Les points communs et les différences d'opinion ont été cernés et débattus lors d'une réunion plénière de l'IPAG-3 à Toronto, Canada, en mai 2000. Au cours de cette réunion, les problèmes essentiels ont été inventoriés et examinés et le plan du présent document a été établi. Les divers membres de l'IPAG-3 ont préparé un texte pour chacun des domaines ainsi définis et ces textes ont été assemblés en un projet de rapport

---

[2] TSPA signifie Total System Performance Assessment.

[3] Le tableau 1 est également reproduit à l'annexe A. On trouvera à la fin de l'annexe A, les références des documents cités dans le tableau 1.

en octobre 2000. Ce projet a ensuite été diffusé pour commentaires aux membres du Groupe d'intégration pour le dossier de sûreté (IGSC)[4] nouvellement constitué.

- Lors de la deuxième réunion de l'IGSC tenue en novembre 2000, une réunion thématique a été consacrée aux méthodes et arguments permettant d'asseoir la confiance. Les résultats des débats au cours de cette réunion ont servi à élucider et affiner davantage les principales observations se dégageant de l'étude.

Le présent rapport, se fonde sur la compilation des réponses au questionnaire et sur les débats lors des réunions de l'IPAG et de l'IGSC. Il relate sur l'expérience pratique des membres de l'IPAG et de l'IGSC acquise sur l'élaboration, la communication et l'examen des méthodes et arguments visant à gagner et asseoir la confiance dans la sûreté à long terme. Comme cela est signalé plus haut, plusieurs auteurs ont établi le rapport, aussi le lecteur peut-il relever des variations dans le style de rédaction d'un chapitre à un autre du rapport. Ce document s'inspire également des commentaires reçus des membres du RWMC, de l'IGSC, de l'IPAG-3 et du FSC, concernant des versions antérieures du projet de ce rapport. Le corps du document décrit les résultats de l'IPAG-3, selon le plan suivant :

- préparer la voie à l'argumentation en vue de gagner la confiance (chapitre 2) ; et
- développer et documenter les arguments pour gagner la confiance (chapitre 3) ;

et présente certaines considérations finales, notamment des observations sur :

- l'expérience de l'IPAG-3 (section 4.1) ; et
- une comparaison des conclusions de l'IPAG-3 avec celles de l'IPAG-1 et de l'IPAG-2 et du document de l'AEN sur la confiance (section 4.2).

On trouvera les annexes suivantes :

- Annexe A : Compilation des réponses au questionnaire ;
- Annexe B : Présenter des exposés oraux sur le dossier de sûreté ;
- Annexe C : Questionnaire de l'IPAG-3 ; et
- Annexe D : Liste des participants à l'IPAG-3.

L'annexe B présente les conclusions d'un sous-groupe de participants à l'IPAG-3 qui s'est réuni lors de la réunion de mai 2000 à Toronto pour échange des points de vue sur le retour d'expérience et les problèmes liés à la présentation d'exposés oraux concernant un dossier de sûreté.

---

4. Ce nouveau groupe reprend des activités menées antérieurement sous l'égide des anciens groupes PAAG et SEDE.

2. PRÉPARER LA VOIE À L'ARGUMENTATION EN VUE DE GAGNER LA CONFIANCE

2.1 La confiance et le processus d'aménagement des dépôts géologiques destinés à des déchets radioactifs à vie longue

Évacuation dans des formations géologiques

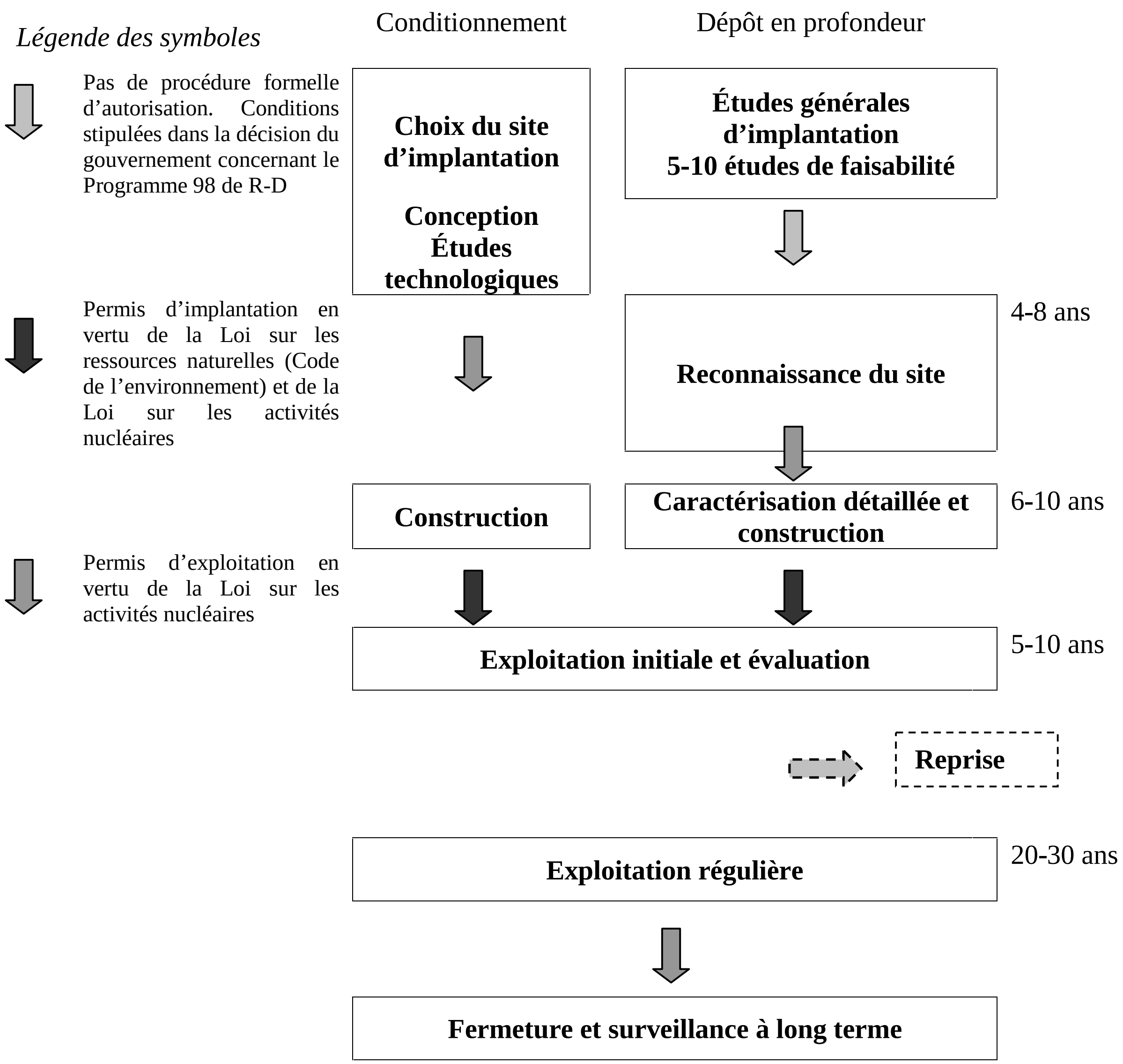
Le concept de stockage géologique appliqué à des déchets radioactifs à vie longue implique des ouvrages souterrains profonds qu'ils assurent la sécurité (par exemple, résistance aux perturbations d'origine malveillantes ou accidentelles) et le confinement (rétention des déchets de manière à ce que ne soient pas libérées des quantités appréciables de radioactivité susceptibles d'atteindre l'environement en surface). Le concept a été élaboré depuis de nombreuses années sur la base d'une évaluation exhaustive et solide des problèmes techniques et des considérations éthiques. Les formations géologiques réceptrices potentielles ont été choisies en raison de leur stabilité à long terme, de leur capacité d'accueillir l'installation d'évacuation des déchets, et également de leur aptitude à empêcher ou à atténuer notablement une éventuelle libération de radioactivité. Cette barrière naturelle est complétée et renforcée par un système ouvragé qui assure le confinement physique et chimique des déchets. La sûreté à long terme et la protection des êtres humains et de l'environnement sont ainsi assurées de manière à n'imposer aucune charge supplémentaires aux générations futures. Les pays Membres de l'AEN ont mis en place des programmes de gestion des déchets radioactifs qui visent en dernier ressort à enfouir les déchets radioactifs à vie longue dans une installation en formation géologique profonde.

Mise en œuvre par étapes

Le développement d'un stockage final géologique profond se caractérise par plusieurs étapes et, dans l'ensemble, exige plusieurs décennies pour être mené à terme. La Figure 1 ci-après illustre pour les combustibles usés la manière pour lequel un tel processus par étapes est actuellement mis en œuvre en Suède.

La durée de ce processus s'explique par la nouveauté et la complexité des tâches liées à l'élaboration d'un concept de dépôt, à l'évaluation de sa faisabilité technologique et de sa sûreté à long terme ainsi qu'à la mise au point des technologies permettant de construire, d'exploiter et de fermer le dépôt. Elle reflète aussi le désir d'avancer à pas mesurés compte tenu des aspects techniques et de l'acceptabilité sociale. À la fin de chaque étape, une décision est prise par une ou plusieurs des parties prenantes (par exemple, l'exploitant, l'autorité de sûreté ou les collectivités locales ou encore le gouvernement de l'État) pour savoir s'il convient de poursuivre et s'il faut adapter les prescriptions visant l'étape suivante. En conséquence, le processus itératif est conçu pour offrir à la société, un certain nombre d'occasions d'intervenir dans le processus de décision.

Figure 1. **Processus par étapes du développement d’un dépôt pour combustible usé en Suède**



Le dossier de sûreté en tant que base pour la prise de décisions

D’une façon générale, un dossier de sûreté constitue l’un des fondements essentiels pour la prise de décision sur le développement des dépôts dans des formations géologiques. On peut définir au sens large le dossier de sûreté comme étant un exposé structuré des éléments d'appréciation, analyses et argumentations visant la sûreté d’une installation proposée ou réelle. Il comprend, de façon toutefois non limitative, une description de l’installation et des principes (isolement à long terme, par exemple) sur lesquels se fonde la sûreté, de même que la stratégie adoptée pour réaliser les principes prévus (par exemple, programme de recherche décrivant la manière dont seront traitées les questions non résolues). Des analyses détaillées des performances à long terme du dépôt sous la forme de calculs de modélisation sont normalement présentées dans une évaluation intégrée des performance et constituent le corps du dossier de sûreté.

Il importe, dans le cas du dossier de sûreté, de communiquer à chaque étape, la base du niveau actuel de confiance dans la décision de poursuivre le projet, et d'indiquer clairement la stratégie adoptée pour résoudre les problèmes qui restent en suspens. En outre, s'agissant d'une décision qui est fortement tributaire de la confiance dans la sûreté, le degré de confiance dans le dossier de sûreté doit correspondre à la confiance requise pour prendre la décision. Si d'autres facteurs interviennent aussi dans la prise de décision (échéances, acceptation par le public, contraintes budgétaires, par exemple), il convient d'en reconnaître l'influence.

Pourquoi la confiance revêt-elle une importance critique ?

Pour des décisions qui sont fondées en partie ou en totalité sur les dossiers de sûreté, il est nécessaire de considérer à la fois les résultats effectifs du dossier de sûreté et la confiance que l'on peut accorder aux résultats et conclusions de ce dossier. On se trouve ainsi placé en position de prendre une décision éclairée comme dans n'importe quel domaine.

La question de la sûreté à long terme des dépôts de déchets radioactifs comporte des gageures particulières s'agissant de la confiance, étant donné la longueur des délais mis en jeu. L'évolution future du système de dépôt peut, par exemple, être affectée par certains facteurs externes incertains tels que les conditions climatiques et les activités humaines futures. Vu qu'il n'est généralement pas possible d'obtenir des réponses définitives dans le cas de systèmes complexes, comment peut-on raisonnablement garantir que tous les phénomènes mis en cause dans l'évolution d'un système ont été cernés et dûment pris en compte dans le dossier de sûreté ? En outre, contrairement à la plupart des autres installations, un dépôt ne peut être ni testé ni observé sur l'échelle de temps pendant laquelle il est destiné à fonctionner. Ses performances à long terme doivent plutôt être extrapolées à partir des résultats d'essais en laboratoire, de calculs et d'observations géologiques. Le dossier de sûreté doit être solidement établi avant la fermeture du dépôt et même avant la mise en place de quantités significatives de déchets, car même s'il est possible d'exercer une surveillance et d'exécuter une intervention, la sûreté à long terme ne doit pas tenir compte de cette éventualité.

Enfin les modèles de dépôts varieront d'un pays à un autre afin de recueillir les types et quantités spécifiques de déchets à évacuer et de tenir compte des caractéristiques particulières des roches réceptrices envisagées. Une confiance suffisante dans le fait que les conséquences radiologiques et non radiologiques n'ont pas été sous-estimées, doit être attestée à la fois par la qualité intrinsèque du site choisi et du concept de stockage envisagé et par la qualité des analyses de performances.

Confiance dans le message et dans le « messager »

Les décisions qui relèvent de la compétence des spécialistes techniques et des dirigeants au sein d'une agence de gestion des déchets, et des organismes réglementaires qui supervisent leurs activités, exigeront des arguments techniques qui donnent confiance dans la faisabilité et la sûreté à long terme des concepts proposés. D'autres décisions peuvent être du ressort des décideurs politiques et du grand public (dans des référendums locaux, par exemple). Ces parties prenantes de non-spécialistes ont aussi besoin d'avoir confiance dans les aspects techniques de l'aménagement du dépôt, mais cette confiance peut se fonder sur des arguments moins techniques et plus qualitatifs. La confiance de ces groupes dans les aspects techniques est étroitement liée à la crédibilité des organisations réglementaires et des agences de gestions de déchets. Ceci est susceptible d'être réalisé s'il est possible d'obtenir de la communauté scientifique élargie qu'elle soutienne les arguments techniques avancés par ces organisations.

2.2 Asseoir la confiance technique dans la sûreté à long terme

Aspects stratégiques

La confiance est essentielle afin de favoriser la prise de décisions. On peut la caractériser comme comportant deux volets principaux : la compétence technique et un « volet affectif », qui est une combinaison des éléments sociaux suivants : transparence, fiabilité, intégrité, crédibilité, loyauté et souci des autres [AEN, 2000b]. Ces deux volets constituent les bases indispensables de la confiance. Une faille perçue dans l'un des éléments du « volet affectif » compromet ce dernier dans son intégralité et ce faisant sape la confiance même. Le volet compétence technique de la confiance signifie qu'il est nécessaire entre autres choses, de se fier au dossier de sûreté et à l'évaluation de performance sur laquelle il s'appuie, qui constituent la base technique de la décision à prendre. Le dossier de sûreté fera l'objet d'un large examen de la part d'experts internes et externes, et de contrôles en regard des besoins de publics variés. À ce titre, il convient que le dossier de sûreté présente les informations de façon claire pour une large audience. Il doit décrire :

- le contexte dans lequel le rapport a été établi ;
- la notion de sûreté, y compris les principaux faits et processus sur lesquels repose la sûreté, et la base de la confiance dans leur fiabilité ;
- les principes et hypothèses qui ont été adoptés, les méthodes qui ont été suivies et les données et informations qui ont été utilisées pour évaluer la sûreté à long terme et instaurer la confiance dans la pertinence de la stratégie globale d'évaluation de la sûreté ;
- les résultats de l'évaluation intégrée des performances (EIP) ;
- les dispositions prévues dans le Programme de recherche, de développement et de démonstration pour démontrer et corroborer plus en détail la notion de sûreté ; et
- les stratégies, tant au niveau de l'évaluation de la sûreté qu'à celui de l'ensemble du programme, en vue de traiter les incertitudes restantes qui revêtent de l'importance pour la sûreté à long terme.

Jusqu'où doit-on perfectionner la sûreté ?

Inévitablement, d'aucun laisseront entendre que les informations fournies dans un dossier de sûreté ou la confiance dans ses conclusions ne sont pas suffisantes pour permettre de prendre la décision attendue. Afin d'aider à situer le dossier de sûreté et son niveau d'élaboration dans le contexte de l'étape d'aménagement du dépôt et de la décision qui doit être prise, ***les participants à l'IPAG 3 préconisent d'aborder explicitement les quatre questions suivantes dans un dossier de sûreté :***

- les limites inhérentes à la modélisation de l'évolution future du dépôt : pour quelle raison demeure-t-il raisonnable de poursuivre le projet ?

- le niveau d’intégration : toutes les informations recueillies sont-elle convenablement utilisées et aboutissent-elles à une représentation cohérente du système ? Sinon quelles sont les incidences potentielles des incohérences non résolues sur la sûreté ?
- l’exhaustivité et la qualité des divers types d’informations et de données dont on dispose pour établir le dossier de sûreté : quelles sont les incertitudes et leurs incidences potentielles sur la sûreté ?
- l’existence de désaccords éventuels entre experts techniques : comment ces désaccords sont-ils pris en compte dans les analyses ?

Ces quatre points illustrent une autre question cruciale : quel niveau de confiance devrait-il être requis pour une décision particulière ? Certains aspects de l’évolution d’un dépôt revêtent de l’importance pour la sûreté, alors que d’autres peuvent n’avoir qu’une influence limitée. Il convient de l’indiquer clairement dans un dossier de sûreté, afin de permettre lors d’un débat de s’engager sur la suffisance du niveau de confiance atteint pour la prise de décision à chaque étape du processus.

Le rôle du processus de décision par étapes dans la construction et l’instauration de la confiance

La démarche par étapes adoptée dans les programmes de gestion des déchets nucléaires offre la possibilité de traiter les problèmes tant techniques que non techniques d’une manière qui puisse être acceptable pour une grande variété de parties prenantes. Cette façon d’aborder la prise de décision par étapes présente les avantages suivants :

- les problèmes subsistants ainsi que les démarches et les perspectives s’offrant pour les résoudre, sont présentés à chaque étape ;
- il est possible d’examiner et de réviser les décisions;
- la confiance en ceux qui sont chargés d’élaborer et d’examiner les dossiers de sûreté et le le développement des dépôts peut être progressivement instaurée et confortée ; et
- la capacité de subdiviser le processus en une série d’étapes, ce qui offre à la société la possibilité de se faire une opinion tout au long du développement.

La prise de conscience que le dossier de sûreté définitif est élaboré de façon progressive dans le cadre d’un processus par étapes revêt une importance cruciale pour l’instauration de la confiance. Le dossier de sûreté doit ainsi être structuré, techniquement argumenté et appuyé par une relation claire avec le processus de prise de décision par étapes, incluant notamment la décision sur le point d’être prise et celles qui seront requises pour les étapes futures.

3. DÉVELOPPER ET DOCUMENTER LES ARGUMENTS POUR GAGNER LA CONFIANCE

Le document de l'AEN sur la confiance [AEN, 1999] propose la description suivante du « dossier de sûreté » :

> *Un dossier de sûreté contient un ensemble d'arguments formulés, à une étape donnée de développement du dépôt, à revoir sur la confiance y on a dans la sûreté à long terme de ce dépôt. Il comprend les conclusions d'une évaluation de la sûreté et un état de la confiance dans ces conclusions. Il doit reconnaître l'existence de problèmes non résolus et fournir des orientations visant les travaux à mener pour résoudre ces problèmes au cours des étapes futures.*

Il faut des arguments pour instaurer la confiance tant dans la sûreté intrinsèque du système d'évacuation que dans son évaluation des performances à long terme. Un dossier de sûreté est établi afin d'étayer une décision lors du processus d'aménagement du dépôt. À ce titre, des arguments pour gagner la confiance sont nécessaires pour montrer qu'il existe une base suffisante d'informations permettant de prendre la décision attendue, et qu'il est opportun d'adopter la ligne d'action préconisée par l'agence de gestion des déchets. Il convient de recourir à une variété d'arguments afin de contribuer à instaurer la confiance et à la communiquer aussi bien aux experts chargés de l'examen technique qu'aux autres parties prenantes.

Le questionnaire de l'IPAG 3 contenait un certain nombre de questions qui étaient destinées à analyser les types de méthodes et d'arguments qui étaient utilisés dans les différents dossiers de sûreté étudiés (tableau 1) afin d'instaurer et de communiquer la confiance. On trouvera à l'annexe A une analyse détaillée de ces méthodes et arguments, et les conclusions globales de cette analyse sont exposées dans le présent chapitre. Une grande variété d'arguments visant à gagner la confiance a été relevée dans les dossiers de sûreté étudiés. Certains de ces arguments étaient fondés sur des stratégies novatrices en vue de susciter la confiance, et on a noté des désaccords quant à l'utilité et à l'opportunité de certaines de ces démarches. Il a toutefois été décidé de récapituler dans ce chapitre l'ensemble des arguments visant à gagner la confiance qui ont été recensés par l'IPAG 3. De cette manière, le rapport de l'IPAG 3 représente la « panoplie » des méthodes et arguments qui ont été utilisés pour instaurer et communiquer la confiance dans les dossiers de sûreté existants et dans les évaluations des performances sur lesquelles ils s'appuient. Un dossier de sûreté donné n'a pas besoin d'inclure tous les types d'arguments qui sont présentés dans ce rapport. Certains ces arguments peuvent ne pas convenir à certains concepts de stockage, et d'autres arguments peuvent se fonder sur des stratégies d'instauration de la confiance qui exigent d'être encore affinées.

Les arguments décisifs recensés dans l'IPAG 3 sont classés par catégorie et récapitulés dans le tableau 2. Ce système de classement est utilisé ci-après pour commenter les conclusions de l'IPAG 3 concernant les méthodes et arguments visant à gager la confiance.

Tableau 2. **Arguments décisifs pour gagner la confiance**

Catégorie	Arguments
Confiance dans le système d'évacuation proposé	• Robustesse intrinsèque du système à barrières multiples • Scénarios incertains et calculs de simulation • Comparaison avec des exemples familiers et des analogues naturels
Confiance dans les données et la connaissance du système d'évacuation	• Qualité du programme de recherche et des études de site • Procédures d'assurance de la qualité • Données provenant d'une variété de sources et de méthodes d'acquisition • Utilisation de techniques formelles de suivi des données
Confiance dans la méthode d'évaluation	• Méthode d'évaluation logique, claire et systématique • Évaluation exécutée dans un cadre auditable vérifiable • Construction de la compréhension à travers une approche itérative • Revue d'éxperts indépendante sur l'approche adoptée
Confiance dans les modèles d'EIP	• Explication de la raison pour laquelle les résultats sont intuitifs • Prise en considération d'autres modèles conceptuels et méthodes de modélisation - simples et complexes • Vérification des modèles par rapport aux expériences et à des observations de la nature • Exercices de comparaisons de modèles • Comparaison avec les analogues naturels • Éléments de preuve indépendants, par exemple informations paléohydrogéologiques
Confiance dans le dossier de sûreté et les analyses d'EIP	• Exposés clairs et justifications des hypothèses • Démonstration du fait que les hypothèses sont représentatives ou empreintes de conservatisme • Études de sensibilité • Stratégies claires de gestion et de traitement des incertitudes • Indicateurs de sûreté • Types d'arguments multiples
Confiance par le biais du retour d'information vers la conception et la caractérisa-tion du site	• Appui pour les éventuelles modifications apportées à la conception de la formule d'évacuation • Qualité et sûreté globales du système d'évacuation

3.1 Confiance dans le système d'évacuation

Il faut des arguments pour illustrer, démontrer et asseoir la confiance dans la sûreté intrinsèque du système d'évacuation. Il convient de concevoir, d'implanter et de construire un système d'évacuation destiné aux déchets radioactifs de manière à favoriser la sûreté intrinsèques et à apporter la garantie que l'ensemble du système conservera son intégrité pendant de très longues périodes. Plusieurs organisations de gestion des déchets radioactifs procèdent au choix de sites d'implantation et à la conception de dépôts géologiques profonds utilisant un système robuste qui comporte des éléments simples, s'appuyant une expérience pratique et des processus bien connus. En évitant les éléments et les phénomènes complexes, les performances techniques et la sûreté de ces systèmes sont plus simples à évaluer. En outre, la sélection de sites dans des régions dénuées de ressources de valeur exceptionnelle contribue à réduire la probabilité d'intrusions humaine futures.

De plus, de nombreuses organisations de gestion des déchets mènent des programmes cherchant à démontrer l'applicabilité des technologies mises en place pour évacuer les déchets radioactifs, par exemple par le biais laboratoires en surface et de laboratoires souterrains de recherche, qui apportent la preuve de la faisabilité du système et instaurent la confiance dans le fait que celui-ci peut être mis en œuvre grâce à des technologies facilement réalisables et démontrables. La majorité des pays Membres de l'AEN estime que les laboratoires souterrains de recherche offrent des avantages qui vont au-delà de ceux liés à la seule R&D. Rendre ces installations accessibles aux parties prenantes par des visites contribuera également à asseoir la confiance dans le projet.

Système à barrières multiples

L'un des dispositifs les plus importants mis en place évacuer les déchets en des formations géologiques profondes repose sur le principe d'un système à barrières multiples. Après fermeture, les dépôts géologiques profonds sont des systèmes « passifs » conçus pour fonctionner sans intervention pendant de très longues périodes, et en tant que telles, ces barrières ne peuvent être entièrement indépendantes. Cependant, un défaut dans une barrière, ne devrait pas compromettre notablement la sûreté à long terme de l'ensemble du système. Généralement, les barrières sont constituées d'une série de composants matériels qui contribuent au confinement et à l'isolement des déchets, protègent les déchets par rapport à l'homme et à l'environnement, et empêchent ou retardent la migration des radionucléides et d'autres contaminants provenant des déchets qui sont susceptibles d'atteindre l'environnement.

Parmi les barrières, on peut citer :

- Les matières de déchets à faible solubilité (en particulier dans le cas des déchets de haute activité vitrifiés) ;
- le gainage du combustible (dans le cas du combustible usé) ;
- un conteneur de longue durée comportant une structure capable de résister aux contraintes ;
- le matériau de remplisage (matériau tampon controle pour la diffusion);
- des matériaux de remblayage et de scellement du dépôt dotés de propriétés chimiques favorables ; et
- la roche hôte de faible perméabilité possédant des propriétés géochimiques et mécaniques stables.

Ces barrières ne présenteront pas toutes de l'intérêt pour tous les systèmes d'évacuation et l'importance relative de chaque barrière dépendra du concept du stockage considéré. Par exemple, certains concepts comportent un surdimensionnement du système de barrières ouvragées (des sur-emballages massifs ou une épaisseur plus importante de matériau anticorrosion et tampon, par exemple), pour tenir compte des incertitudes afférentes aux performances des barrières et fournir une marge supplémentaire afin de répondre aux exigences réglementaires. D'autres concepts peuvent tabler davantage sur le maintien de conditions chimiques favorables dans le champ proche et sur le comportement de la géosphère.

Tous les systèmes d'évacuation représentés dans l'étude de l'IPAG comportent en commun un système à barrières multiples dont la définition exacte peut toutefois varier d'un pays à un autre. Par exemple, la plupart des pays considèrent qu'une barrière est une obstruction matérielle, telle qu'une barrière ouvragée ou la géosphère. Cependant, certains pays étendent cette définition de manière à inclure les processus physiques et chimiques qui empêchent ou retardent le rejet ou la migration des radionucléides. En conséquence, ***l'IPAG-3 recommande que les agences de gestion des déchets définissent clairement ce que recouvre la notion de barrières multiples dans leur dossier de sûreté, notamment les éventuelles exigences imposées par la sûreté à long terme.***

Il existe essentiellement trois démarches pour déterminer le caractère approprié d'un système à barrières multiples :

- l'évaluation de l'efficacité de la barrière face à un scénario donné (à l'aide de résultats de calculs de relâchement et de transport de radionucléides) ;
- l'examen de l'évolution des barrières (notamment par l'analyse des caractéristiques, événements et processus ainsi que des scénarios) afin de déterminer la manière dont les barrières peuvent évoluer dans le temps ; et
- l'étude des conséquences d'une efficacité moindre (ou de la défaillance) d'une ou plusieurs barrières sans nécessairement expliquer comment cette situation pourrait se produire. Ces calculs sont parfois qualifiés de « calculs de simulation ».

L'IPAG-3 a constaté que les dossiers ont pour la plupart recours à chacune de ces trois démarches et que celles-ci constituent la majeure partie d'une évaluation intégrée de performance. Par exemple, l'efficacité des barrières a été évaluée en déterminant les performances qualitatives de chacune d'entre elles eu égard aux radionucléides qui seraient confinés par cette barrière du fait de ses propriétés, et en exécutant une série de calculs pour décrire la manière dont les différentes barrières contribuent à l'isolement et à la sûreté. Le Tableau 3 récapitule les types de scénarios qui ont été analysés dans les différents dossiers envisagés dans le cadre de l'IPAG-3 lorsque les barrières ont été supposées être moins efficaces que prévu ou inexistantes.

Tableau 3. **Exemples de scénarios dans lesquels les barrières ont été supposées moins efficaces que prévu ou inexistantes**

Barrière	Scénario
Matrice des déchets	• L'ensemble des combustibles usés relâche aussitôt que l'emballage des déchets cède : pas de prise en compte de l'effet du gainage du combustible • Dégradation rapide du combustible • Fraction de radionucléides libérée instantanément plus importante que prévue
Conteneur	• Défaut initial (petite perforation) • Défaillance précoce (absence de rétention dans le cas de certains conteneurs) • Défaillance massive (absence de rétention pour tous les conteneurs)
Matériau tampon	• Valeurs de rétention conservatives (autrement dit faibles) • Solubilité illimitée • Épaisseur réduite de la masse tampon (due à la dégradation) • Masse tampon agissant comme un réservoir de mélange à circulation traversière

Barrière	Scénario
Scellements	• Perméabilité accrue
Geosphère	• Galerie située plus ou moins près d’une zone fissurée. • Perméabilité accrue • Temps de parcours rapide • Débits très élevés • « Court-circuit » (non prise en compte de la rétention dans la geosphère). • Un important mouvement de terrain postglaciaire frappe le dépôt dans 30 000 ans, brise les conteneurs, déplace la bentonite, amplifie les écoulements et le transport et crée des conditions oxydantes dans l’ensemble du champ proche et de la géosphère. • Perte totale de la barrière constituée par la géosphère par suite de l’érosion ou d’une intrusion humaine importante.

Comparaisons avec les analogues naturels

Les concepts de stockage actuels ont recours à des matériaux connus tels que le fer et le cuivre pour les conteneurs et les matériaux à base d’argile et de ciment pour le remblayage et le scellement. De nombreuses données et informations scientifiques sont disponibles sur ces propriétés, la pérennité à long terme et les processus de dégradation de ces matériaux. Dans certains cas les données sur les analogues naturels sont également disponibles, et peuvent contribuer à l’évaluation des performances à long terme de ces matériaux. La plupart des agences de gestion des déchets mènent des programmes de recherche et de développement afin de poursuivre l’étude des propriétés et des caractéristiques des matériaux constituant les barrières, et ce faisant de compléter les connaissances générales relatives à leurs propriétés à long terme. Par exemple, elles se penchent sur les capacités de résistance et processus de corrosion à long terme des conteneurs de déchets, l’évolution des matériaux tampon au cours de la resaturation et l’évolution à long terme de la composition de l’eau souterraine.

Pour la plupart des organisations, la démonstration de l’efficacité des barrières repose sur les résultats d’expériences et sur des données mesurées lorsque cela est possible. Des arguments qualitatifs sont aussi présentés en complément des informations et arguments quantitatifs. Par exemple, les données sur des analogues naturels ont été utilisées dans la mise au point de modèles relatifs au terme source ; et des informations qualitatives et les analogues naturels sont servi d’arguments support pour l’évaluation des performances des barrières ouvragées.

3.2 Confiance dans les données et dans la connaissance du système de stockage

Bon nombre des problèmes liés à l’élaboration d’un dossier de sûreté et de l’EIP associé, tiennent au fait qu’il est nécessaire de démontrer les performances du système sur des dizaines de milliers d’années, voire davantage. On possède une certitude concernant certains aspects déterminants du concept dans des formations géologiques profondes, la décroissance radioactive des radionucléides avec le temps, par exemple. Cependant, il existera inévitablement des incertitudes visant les phénomènes et les données sur de grandes échelles de temps, telle que l’incertitude relative au déroulement futur d’événements externes et l’évolution à long terme des matériaux des ouvrages de stockage. L’incertitude entachant l’évolution des matériaux est tributaire de l’étendue des connaissances disponibles sur leur propriétés, en ce qui concerne tant les processus mis en jeu que les conditions au moment de la fermeture du dépôt.

Il est nécessaire qu'une évaluation intégrée de performances traite de façon exhaustive de telles incertitudes et montre que, sur la base des données et informations disponibles et compte tenu des incertitudes, il est permis d'escompter que le stockage assure la protection à long terme de homme et de l'environnement. La sûreté globale sera plus fortement affectée par certaines incertitudes que par d'autres, et les participants à l'IPAG-3 ont observé qu'il est avantageux d'essayer de cerner et de traiter de telles sensibilités dès le début de l'élaboration du concept de stockage. En général, plus les marges de sûreté dans les performances des barrières sont élevées, moins les exigences visant la précision des données associées sont rigoureuses. En d'autres termes, l'acquisition des données est susceptible d'être guidée par la nécessité d'améliorer la confiance dans des aspects spécifiques des performances du système. En conséquence, l'élaboration d'une évaluation de performances peut fournir d'importantes données de départ quant à l'orientation des programmes de recherche.

Le calcul de l'évolution dans le temps d'un système de dépôt repose sur une multitude de paramètres décrivant les propriétés des matériaux mise en place. Bon nombre de ces données sont tirées d'observations expérimentales effectuées au cours de la caractérisation du site ou d'études en laboratoire. Les réponses de l'IPAG-3 indiquent clairement que les programmes s'appuient pour la plupart sur d'importantes activités de recherche et de développement. La nécessité d'une bonne connaissance scientifique du système est ainsi pleinement reconnue par l'IPAG-3.

La caractérisation du site est nécessaire pour confirmer que le site étudié possède bien les propriétés qui conviennent à un stockage. Les travaux de caractérisation du site contribuent également à une connaissance théorique des particularités et des processus existants se produisant à l'intérieur et autour du dépôt. Une connaissance suffisante de l'état actuel et de l'évolution antérieure du site dépendra de la qualité tant des données disponibles que de leur interprétation. Afin d'éviter les pièges potentiels de l'interprétation erronée, il sera nécessaire de réunir une équipe d'experts couvrant un large éventail de disciplines scientifiques. Les participants à l'IPAG-3 ont en particulier relevé que les données paléohydrogéologiques constituent une source possible d'informations sur les mécanismes de transport sur de très longues échelles de temps. Ils ont en outre observé que la confiance dans la connaissance générale du système pourrait être renforcée si les conclusions relatives au comportement à long terme sont compatibles avec les données tirées d'observations portant sur des analogues naturels.

La connaissance du site et des processus y afférents constitue un important point de départ pour une transposition aux états futurs du système et une condition préalable essentielle pour une modélisation numérique des processus lors d'évaluation des performances. Lorsque l'on applique la base des connaissances à la prévision des performances, il faut pouvoir porter un jugement rationnel sur la qualité des résultats des recherches et des données. En revanche, la sûreté du dépôt n'est pas influencée par tous les menus détails de l'évolution future du site. Une connaissance complète d'un site et de ses caractéristiques est en fait non seulement irréalisable, mais aussi superflue. Des incertitudes sont acceptables du moment que leurs répercussions puissent être limitées. Le dossier de sûreté devrait expliquer la mesure dans laquelle il est possible d'y parvenir, par exemple à l'aide de certains des arguments exposés plus loin dans le présent chapitre.

La confiance dans les données utilisées dans le dossier de sûreté repose sur l'assurance que les travaux de recherche ont été convenablement exécutés et que les données ont été correctement comprises et interprétées dans le cadre de l'évaluation des performances. Il est donc essentiel de disposer d'une documentation traçable de toutes les données et de registres transparents relatifs à leur utilisation, constituant la base d'un système approfondi de contrôle de la qualité de nature à instaurer la confiance dans les données. Le système de contrôle de la qualité des données devrait aussi permettre de vérifier et de justifier les éventuelles modifications ultérieures apportées aux données utilisées dans une analyse de sûreté, par exemple, lorsque de nouvelles données améliorées deviennent disponibles. Certains participants de l'IPAG-3 ont fait état de méthodes systématiques de gestion interne des données parmi les outils indispensables pour asseoir la confiance dans ces données.

Toutes les données ne sont pas le fruit de travaux menés dans le cadre d'un programme spécifique sur le stockage. Les principes de conception reposent pour la plupart sur des connaissances scientifiques déjà établies et sur des relations fondamentales telles que la conservation de la masse et la thermodynamique. Certains participants ont observé que la confiance dans la qualité des données et leur interprétation peut être renforcée par l'emploi de données tirées d'une base élargie, par exemple de données indépendantes recueillies par des groupes non directement liés au programme de stockage, ou de données obtenues à partir de techniques de mesure différentes. Il se peut qu'une base de données de ce type ne soit pas toujours réalisable et soit davantage susceptible d'être disponible pour des données plus générales. Il est alors recommandé de rechercher et d'exploiter toutes les sources de données pertinentes disponibles, ou du moins de les rapprocher des données qui seront à utiliser dans l'évaluation de performance.

Vu l'horizon temporel applicable à la mise au point d'un projet de stockage, de même que sa complexité, il importe de conserver des registres explicites de toutes les décisions importantes. Il s'agit des décisions relatives à la conception et au choix du site d'implantation du dépôt, à la planification et à la mise en œuvre du programme de recherche, à l'interprétation des données observées, à l'élaboration de modèles conceptuels et à la représentation de ces modèles conceptuels dans le cadre de l'EIP. ***Il est recommandé d'énoncer clairement les hypothèses essentielles et leurs justifications dans une section spécifique de la documentation.*** S'agissant d'aider à instaurer la confiance, cette documentation devrait également expliquer les cas où d'éventuelles hypothèses sont empreintes de conservatisme, car ces hypothèses représentent des « marges de sûreté » et contribueront à la surestimation des incidences globales (Voir également les remarques formulées dans l'IPAG-2 [AEN, 2000-a]).

3.3 Confiance dans la méthode d'évaluation

Les participants à l'IPAG-3 ont noté qu'il existe un large consensus international sur la méthode générale appliquée pour exécuter une EIP, soulignant que cela pourrait contribuer à instaurer la confiance dans la méthode spécifique adoptée.

Il convient d'exécuter une évaluation de la sûreté dans un cadre vérifiable, conforme à un cadre réglementaire qui est explicite et admis par les parties prenantes. La méthodologie d'évaluation devrait être systématique et logique, indiquant clairement les caractéristiques, événements et processus (FEPs) pris en considération et les raisons pour lesquels certains ont été exclus. Les participants à l'IPAG-3 utilisent pour la plupart des listes de FEPs sous une forme ou une autre comme point de départ d'une évaluation. Plusieurs participants passent à l'emploi d'analyses plus détaillées des FEPs afin de définir un ensemble complet de scénarios destinés à représenter l'évolution potentielle du système de stockage. D'autres prennent en compte des scénarios « best estimate » and « worst estimate », mais il peut être difficile de se mettre d'accord avec les parties prenantes sur ce qui constitue « l'hypothèse la plus défavorable ». La publication des listes de FEPs et la recherche d'un retour d'information de la part des parties prenantes visant les éventuels « FEPs manquants » a été considéré comme un élément important dans la démonstration de l'exhaustivité du traitement de tous les FEPs pertinents, spécialement en l'association à une démarche systématique usant à de démontrer la manière dont chaque FEPs est représenté dans les modèles d'évaluation.

Par ailleurs, un stockage est développé en plusieurs étapes, et les concepts préliminaires sont progressivement traduits en propositions techniques. Les sites sont sélectionnés puis font l'objet d'une reconnaissance à la surface par le biais de sondages et finalement en souterrain. La méthode d'évaluation devrait également être suffisamment souple pour permettre l'intégration d'éventuelles données ou connaissances nouvelles. À ce titre, tous les participants à l'IPAG-3 adoptent ***une démarche itérative*** en s'efforçant continuellement d'apporter des améliorations à la méthode, aux données et aux modèles. À l'intérieur de ce cadre itératif, il importe de démontrer comment chaque cycle d'évaluation est une prolongation logique des précédents. Le fait qu'une suite d'évaluations fournisse des résultats et des conclusions homogènes sur un certain nombre de cycles d'itération, contribue à instaurer la confiance sur ce qui caractérise réellement la sûreté globale du système.

Les procédures d'assurance de la qualité contribuent notablement à asseoir la confiance dans la méthode d'évaluation. En particulier, elles constituent un moyen permettant de repérer dans la documentation les données d'entrées et les sources d'informations. Il a été considéré comme essentiel de rendre publication du dossier de sûreté et des EIP accessible au public, de préférence sous une présentation hiérarchisée et transparente à laquelle peut accéder toute une variété de parties prenantes. Certains participants à l'IPAG-3 ont estimé que des formats de rapport standardisés provenant d'un commun accord pourraient être avantageux.

L'évaluation par des experts interne ou externe, constitue également un important facteur de confiance dans la démarche globale. ***Lors de la publication d'un dossier de sûreté et d'une EIP, il est recommandé d'indiquer clairement dans quelle mesure les travaux ont été examinés et par qui.***

3.4 Confiance dans les modèles

Une EIP devrait présenter un enchaînement logique d'arguments techniques, démontrant une connaissance scientifique rationnelle et suffisante. Il convient d'indiquer clairement la base de la confiance dans les modèles utilisés et dans les résultats obtenus, autrement dit d'expliquer pourquoi les résultats conviennent à la prise de décision. On pourrait ainsi expliquer notamment la raison pour laquelle les résultats sont intuitifs et correspondent à la connaissance du système global d'évacuation, et la manière dont des observations indépendantes ou des expériences à l'échelle pilote ou effectuées *in situ* les confortent.

La confiance dans les modèles exige à la fois d'être convaincu que ces modèles représentent tous les FEPs pertinents et qu'ils sont capables d'évaluer les performances du système de dépôt avec une précision ou une prudence suffisantes. Une EIP devrait par conséquent démontrer clairement la manière dont les spécifications des modèles ont été déduites des études analytiques des FEPs et dont ces modèles ont été construits sur la base des données et des connaissances. Le cas échéant, il peut être nécessaire d'envisager d'autres modèles conceptuels qui sont étayés par les données disponibles.

Méthodes de modélisation

La méthode de modélisation devrait être explicite et transparente. Une hiérarchie de modèles, allant de modèles relatifs à des processus détaillés spécifiques au système de dépôt, peut aider à la transparence des méthodes de modélisation. Une telle démarche peut aussi être utilisée pour démontrer la manière dont divers FEPs contribuent aux mesures des performances globales et à l'incidence d'éventuelles hypothèses simplificatrices.

Pour instaurer la confiance dans des modèles complexes détaillés il est possible de recourir à des modèles simples, par exemple des modèles analytiques donnant « un aperçu », reflète les processus physiques et chimiques déterminants et contribuant à la compréhension des performances d'un système de stockage. Si l'on peut montrer que différentes techniques de modélisation donnent des résultats similaires, cela contribue aussi à asseoir la confiance dans les résultats de la modélisation. Plusieurs participants à l'IPAG-3 ont évoqué l'intérêt de vérifier une modélisation numérique par une comparaison avec des modèles analytiques simples, des solutions à des problèmes expérimentaux et des comparaisons de résultats obtenus par différentes méthodes utilisées pour résoudre le même problème. L'auteur de l'une des réponses a mentionné que la confiance dans le bien fondé des modèles de transport pourrait procéder de l'observation selon laquelle la poursuite des essais sur le terrain n'a pas révélé d'éventuels mécanismes nouveaux nécessitant d'être pris en compte.

Parmi les autres stratégies déployées pour instaurer la confiance dans les modèles, figure aussi la participation à des travaux internationaux de comparaison. Certains utilises, notamment des modèles pour prévoir les paramètres mesurables (par exemple, en calculant le temps nécessaire à l'eau souterraine pour revenir dans le réseau de surface, et en montrant qu'il peut être conforme aux mesures géochimiques). D'autres se basent sur des comparaisons de résultats avec les analogues naturels, ainsi que les données paléohydrogéologiques. Par exemple, si un modèle permet de reconstituer et d'expliquer des conditions passées, ou fournit une description cohérente et intégrée des conditions présentes, on aura alors davantage confiance dans sa transposition sur des conditions futures.

Rôle des études relatives aux analogues naturels et de paléohydrogéologie dans la modélisation

Les participants à l'IPAG-3 utilisent pour la plupart des arguments fondés sur des analogues naturels et sur la paléohydrogéologie dans leurs évaluations, un certain nombre de méthodes différentes ayant été recensé. Certains utilisent les analogues naturels pour fixer des valeurs limites aux incertitudes : des données sur des analogues naturels ont par exemple été utilisées pour imposer des limites aux valeurs de solubilité des radionucléides. Dans d'autres cas, on a eu recours à des analogues naturels pour examiner les processus et les mécanismes spécifiques, pour asseoir la confiance dans les données expérimentales et les modèles relatifs au transport de radionucléides et pour renforcer les connaissances et la confiance dans la mise en œuvre des caractéristiques et des processus sur des échelles de temps qui sont hors de portée de l'expérimentation.

Parmi les exemples de recours aux analogues naturels mentionnés par les participants à l'IPAG-3:

- les recherches exécutées sur des gisements d'uranium naturel et les observations afférentes à Cigar Lake et à Oklo ont été utilisées pour étayer la conviction suivant laquelle l'oxyde d'uranium et ses produits de fission pourraient être efficacement immobilisés pendant des milliards d'années dans certains milieux géochimiques ;
- Les anciens tombeaux en Chine et au Japon ont été utilisés comme analogues archéologiques pour les performances à long terme de structures artificielles de souterrainement ;
- les propriétés en matière de corrosion à long terme de l'acier et du cuivre ont été démontrées par référence à des artefacts archéologiques ;

- la stabilité à long terme de la bentonite a été confirmée par le fait que l'on n'observe guère voire pas de modification minéralogique dans les sédiments riches en montmorillonite ;
- la résistance à la corrosion de la matrice vitreuse des déchets de haute activité peut être déterminée par comparaison avec les faibles taux de corrosion du basalte naturel et des anciens verres d'origine anthropogénique ;
- la faible solubilité et/ou l'immobilisation de certains éléments, par exemple l'uranium et le thorium, a été étayée par des mesures effectuées sur les minéraux des roches et les eaux souterraines adjacentes ; et
- les recherches portant sur d'anciens dépôts radioactifs et des décharges modernes ont été utilisées pour obtenir des informations relatives à la dégradation des matériaux cellulosiques.

Les participants à l'IPAG-3 ont relevé que, dans le cas des arguments fondés sur des analogues naturels, il est nécessaire de caractériser de façon suffisamment détaillée tant le site de l'installation d'évacuation que celui de l'analogue, pour démontrer que les conditions afférentes à l'analogue sont applicables au site de l'installation d'évacuation.

Dans certains cas, les participants à l'IPAG-3 ont eu recours à la paléohydrogéologie. Certains la considèrent comme faisant partie intrinsèque de la caractérisation du site et de la modélisation des eaux souterraines. Par exemple, elle a joué un rôle majeur dans la mise au point des paramètres relatifs des eaux souterraines dans le cas de Yucca Mountain (Nevada, États-Unis), et la chimie des eaux souterraines a joué un rôle important en restreignant les flux et les vitesses dans les zones non saturées de ce site. Les études paléohydrogéologiques ont le plus souvent été utilisées pour essayer de comprendre et de modéliser les évolutions géochimique et hydrogéologique passées sur le site proposé, en particulier en ayant recours à la signature isotopique de l'eau souterraine pour indiquer son temps de confinement depuis l'apport d'eaux météoriques. L'étude de la migration du thorium et de l'uranium dans l'argile naturelle a aussi été utilisée pour montrer l'extrême lenteur de la migration des actinides dans de telles argiles. Le recours aux informations paléohydrogéologiques provenant du site renforce généralement sa connaissance et la crédibilité de la modélisation du transport, pour représenter de l'évolution future du site. Alors que de telles études peuvent être utilisées pour fixer des limites aux données destinées au modèle de migration, on peut également noter que le temps de séjour de l'eau souterraine ne donne pas nécessairement une indication directe du temps de transit cette eau du stockage à la biosphère.

3.5 Confiance dans les analyses du dossier de sûreté et de l'EIP

On s'accorde à reconnaître que le traitement explicite des incertitudes constitue un facteur essentiel contribuant à instaurer la confiance dans les analyses du dossier de sûreté et de l'EIP. Les incertitudes peuvent être liées aux données d'entrée, aux modèles utilisés et à l'évolution future du système de stockage, notamment à d'éventuelles interventions humaines futures. Les réponses au questionnaire ont mis en évidence un certain nombre de suggestions en vue d'une évaluation systématique de l'évolution du système de dépôt tenant compte des incertitudes.

Gestion et traitement des incertitudes

L'IPAG-3 considère qu'il est important de disposer d'une stratégie claire sur le traitement des incertitudes. Cette stratégie devrait être expliquée dans le dossier de sûreté et l'EIP sur laquelle il s’appuie, en démontrant la manière dont elle est appliquée à chaque étape de l’analyse de sûreté. En particulier, ***la confiance dans les analyses devrait être motivée par des prises de position explicites sur la qualité des données, des justifications des hypothèses adoptées et une analyse des sensibilités des performances du système aux incertitudes des paramètres.***

Les incertitudes entachant les données peuvent être abordées par des évaluations probabilistes de sûreté, qui permettent un traitement systématique des effets de l’incertitude afférente aux paramètres d’entrée. Certaines organisations utilisent des études de sensibilité déterministes qui sont utiles pour examiner l’incidence de l’incertitude entachant un paramètre particulier. Quelques organisations ont mené des vérifications à travers des audits pour calculer les sensibilités aux données et hypothèses utilisées dans les modèles. Des hypothèses simplificatrices empreintes de conservatisme, qui surestiment les conséquences sont aussi largement employées. Certains participants à l’IPAG-3 ont fait valoir que les effets de telles simplifications sur les indicateurs de performance doivent être bien compris et interprètes dans une évaluation de performances.

Une sélection systématique des scénarios, fondée sur l’analyse des FEPs, constitue la méthode préférentielle pour traiter les incertitudes afférentes à l’évolution du système de stockage. En l’occurrence, on se fonde généralement sur un scénario de base ou de référence et sur une gamme de variantes de scénarios permettant d’évaluer les incidences sur la sûreté à long terme des incertitudes afférentes à l’évolution du dépôt. Certaines organisations adoptent un scénario de référence simplifié ; d’autres ont recours à un scénario de base couvrant l’évolution naturelle ou escomptée du système. D’autres démarches consistent notamment à considérer des scénarios « réalistes » (afin de démontrer l’effet de l’élimination des hypothèses empreintes de conservatisme) et des scénarios reposant sur l’hypothèse la plus défavorable ou dits « robustes » (en choisissant, par exemple, des paramètres correspondant au modèle le plus défavorable). Certains participants à l’IPAG-3 ont utilisé des scénarios de simulation afin de démontrer la redondance des barrières (surtout dans le cas des déchets de haute activité ou du combustible usé) ou dans le cadre d’analyses quantitatives de sensibilité pour démontrer la manière dont divers composants du système contribuent à la sûreté (cf. section A 3.2). Les analyses des dossiers de sûreté et des évaluations intégrées de performances devront apporter la preuve que les incidences sur la sûreté à long terme des incertitudes entachant les états futurs ont convenablement été prises en compte et évaluées dans l’analyse du scénario.

Indicateurs multiples de sûreté

Le plupart des participants à l’IPAG-3 prennent en considération l’évolution de l’ensemble du système, et non pas simplement le transport des radionucléides. De nombreuses organisations utilisent d’autres indicateurs de sûreté, en complément aux calculs de risque et de dose pour l’individu. Parmi les exemples d’indicateurs, autres que les débits de dose ou la risque individuel couramment utilisés dans les analyses ; on peut notamment citer :

- la comparaison du débit de dose avec les niveaux de dose naturelle de rayonnement ;
- les calculs de dose collective ;
- le calcul des flux de radionucléides à la sortie de chaque barrière afin d’illustrer leur capacité d’atténuation des rejets de différents radionucléides ;
- la comparaison des rejets de radionucléides avec le volume du milieu naturel qui renfermerait la même quantité de radioactivité ;
- la comparaison des concentrations de radionucléides à certains points avec les niveaux existant dans la nature ;

- l'évaluation des incidences de la toxicité chimique par la comparaison des concentrations estimées dans la biosphère avec les concentrations d'origine naturelle et avec l'accroissement ambiant ;
- le calcul des débits de dose aux organismes vivants ou les évaluations des risques écologiques pour certains organismes vivants non humains se trouvant sur le site ;
- le calcul des échelles de temps pendant lesquelles les diverses barrières assurent l'isolement, par exemple la durée pendant laquelle les barrières ouvragées confinent les déchets ou les temps de parcours des eaux souterraines ;
- le devenir de radionucléides spécifiques dans les systèmes ouvragés : leur migration et leur décroissance ;
- le calcul de l'évolution dans le temps de radionucléides sélectionnés dans différents composants du système de stockage ;
- le calcul des fractions de l'inventaire initial qui atteignent effectivement la géosphère et la biosphère ;
- l'examen en fonction du temps de la distribution spatiale de la radiotoxicité entre les composants des barrières ; et
- Les comparaisons avec les niveaux de libération proposés par l'AIEA [1996] pour l'exemption de matières de faible activité du contrôle réglementaire.

Les autres indicateurs de performances les plus couramment utilisés sont les flux de radionucléides sortant des barrières à l'intérieur du système de stockage. Certains dossiers prennent aussi en considération les risques radiologiques pour les espèces non humaines, l'incidence potentielle sur les conditions écologiques et l'effet sur la qualité de l'eau souterraine des contaminants non radiologiques provenant d'un dépôt. Plusieurs organisations, n'utilisant pas encore d'autres indicateurs, ont indiqué qu'elles projetaient de les intégrer dans leur prochaine évaluation, attestant ainsi de l'intérêt croissant porté sur ce sujet.

Types d'arguments multiples

Les types d'arguments multiples sont un ensemble d'arguments complémentaires qui utilisent différentes démarches ou preuves permettant de construire la confiance dans les analyses. Il est possible d'utiliser une argumentation multiple tant qualitative que quantitative, notamment par des calculs exploratoires et des valeurs des limites supérieures, des analogues naturels et une variété d'indicateurs de sûreté. L'argumentation n'est pas tenue de traiter tous les aspects de la sûreté, pas plus qu'elle ne doit être complètement indépendante des autres axes d'argumentation. Un avantage particulier offert par le recours des types d'arguments multiples tient notamment à ce que des arguments différents peuvent avoir davantage de résonance auprès d'audiences différentes.

La nature des arguments à utiliser dépend du contexte. Parmi les exemples mentionnés dans le questionnaire de l'IPAG-3, on peut citer les suivants parmi lesquels un bon nombre d'entre eux ont été examinés dans des sections précédentes :

- Les arguments qualitatifs qui soulignent la nature robuste et réalisable du concept, en particulier par l'utilisation de matériaux connus ;
- dans le cas de systèmes de stockage destinés à des déchets de haute activité et/ou au combustibles usés, les arguments qui démontrent l'intégrité des conteneurs de déchets pendant une très longue période ceci dans les conditions attendues d'évolution du stockage ;

- l’explication de l’endroit où se situent les marges de sûreté dans l’analyse, par exemple, des endroits où des FEPs renforçant la sûreté ont été négligés dans l’évaluation et l’indication de leur incidence probable sur les mesures de performance du dépôt ;
- l’évaluation des conséquences des défaillances et/ou défauts des barrières potentielles, à savoir l’analyse de la redondance dans le système à barrières multiples.
- le recours à des modèles « indicatifs » simples parallèlement à des modèles d’évaluation plus complexes afin d’améliorer la transparence des modèles et de faciliter leur vérification ;
- les arguments paléohydrogéologiques, tels que l’étude du comportement et de la migration des radionucléides présents dans la nature ou d’autres éléments pertinents se trouvant sur le site étudié (voir aussi section A.4.2).
- les arguments fondés sur l’utilisation d’analogues naturels (pour des exemples spécifiques, voir section A.4.2) ;
- les autres indicateurs de sûreté (par exemple, évaluation des risques écologiques, incidence des rejets de contaminants non radioactifs sur la qualité de l’eau souterraine, rapprochement des doses calculées et des niveaux du fond naturel de rayonnement - voir également la section A.4.3) ;
- l’introduction d’exemples simples, mais quantitatifs, pour situer dans son contexte le risque en fonction du temps représenté par les déchets ;
- dans le cas d’installations de stockage destinées à des déchets de faible activité, les arguments selon lesquels la majeure partie de l’inventaire est à vie courte et subira une décroissance radioactive pendant qu’elle se trouve dans les ouvrages de stockage ;
- les comparaisons avec d’autres évaluations intégrées des performances et démonstration de l’existence d’une cohérence avec le consensus international qui se dégage concernant la manière d’exécuter des EIP.

Le questionnaire de l’IPAG-3 a mis en évidence quelques appréciations intéressantes portées par les autorités de sûreté sur le recours des types d’arguments multiples. Plusieurs autorités de sûreté ont relevé que de tels arguments avaient fait défaut dans les évaluations examinées. D’une façon générale, les autorités de sûreté ont encouragé le recours à d’autres axes d’argumentation, sans toutefois spécifier comment il convient de les articuler. Certains membres de l’IPAG-3 ont aussi relevé que les arguments qualitatifs pourraient moins se prêter aux critiques car ils ont tendance à susciter moins de commentaires négatifs de la part des examinateurs, contrairement aux nombreuses critiques visant les méthodes, modèles et donnés quantitatifs. En particulier, des arguments « raisonnables » qui couvrent les longues périodes de temps semblent être bien reçus.

3.6 Confiance par le biais du retour sur la conception et la caractérisation du site

L’élaboration d’un dossier de sûreté et de son évaluation de performances, n’a pas pour seule finalité de démontrer de façon probante qu’il est possible de garantir la sûreté. La modélisation et les analyses offrent le moyen d’examiner et de réactualiser les hypothèses, les données et les modèles, de même que de modifier les options de conception afin d’améliorer le système de stockage. En particulier, l’évaluation de performances est nécessaire pour vérifier si les modifications de conception suggérées ou les propriétés mesurées du site potentiel aboutissent toujours à un système global sûr. Le processus itératif d’échanges d’informations entre une EIPs et la mise au point du modèle de système d’évacuation et la caractérisation du site peuvent contribuer notablement à susciter la confiance dans la qualité et la sûreté du système tel qu’il sera finalement mis en œuvre. L’expression de la confiance dans un dossier de sûreté devrait inclure appréciation des améliorations observées sur la compréhension du système de stockage et sur la qualité de la méthode et des analyses d'évaluation.

La modélisation permet de hiérarchiser les principaux facteurs déterminant les performances du système de stockage, et contribue ainsi à définir les programmes de recherche et à les classer par ordre de priorité. Le poids des incertitudes entachant les résultats intermédiaires et final peut être réduit en améliorant les connaissances relatives aux modèles, paramètres ou données qui revêtent le plus d'importance eu égard à leur incidence sur l'évaluation de la sûreté. Sur la base d'une amélioration des connaissances, il est possible de proposer de nouvelles options de conception ou un nouvel ensemble de calculs (nouvelle itération). À chaque stade de l'élaboration du dossier de sûreté et de l'EIPs, l'avantage d'entreprendre des recherches supplémentaires peut alors être apprécié. Un tel processus itératif fait partie de la démarche globale en vue de susciter la confiance.

Si, pour un modèle donné, les travaux de recherche scientifique et d'investigation sur le site ne permettent pas de ramener les incertitudes en dessous du niveau requis, la conception du système d'évacuation peut être adaptée ou modifiée de manière à permettre la mise en conformité avec les prescriptions en matière de sûreté. Le processus de l'évaluation de performance bénéficie ainsi de la prise en compte du retour d'information dans l'itération suivante, par exemple, par l'intermédiaire d'une meilleure qualité des données et une amélioration des modèles, et/ou d'une conception améliorée. Ce processus itératif, entre l'analyse et la conception du système, jouent un rôle important dans l'instauration de la confiance dans le système stockage et le dossier de sûreté ainsi que son évaluation de performances.

Alors que l'IPAG-3 n'a pas mis en évidence de nombreux exemples dans lesquels le retour d'information a contribué à susciter la confiance, la compilation des réponses au questionnaire figurant à l'Annexe A montre que plusieurs organisations projettent de mieux exploiter ce retour d'information dans les travaux futurs.

4. CONSIDÉRATIONS FINALES

4.1 L'expérience de l'IPAG-3

Le nombre d'organisations qui ont participé, la qualité des réponses au questionnaire et les apports fournis à point nommé en vue de l'établissement du présent rapport témoignent de l'intérêt porté à l'IPAG-3. A chacune des phases successives de l'IPAG, la participation s'est accrue, passant de dix organisations dans la Phase 1 à vingt dans la Phase 3. En outre, les sujets et les problèmes examinés sont devenus progressivement plus conceptuels et subjectifs tant au long des trois phases de l'IPAG. Du fait de cette dynamique, la mise en œuvre de la démarche adoptée pour l'IPAG, qui consiste à recueillir des informations sur la base des dossiers de sûreté, des évaluations des performances intégrées et des examens existants par l'intermédiaire d'un questionnaire, puis à examiner et analyser ces informations dans le cadre du groupe de travail plénier, a été particulièrement challenge délicate dans le cas de la Phase 3.

Néanmoins, l'IPAG-3 a offert un cadre de rencontre utile qui a permis aux participants de se mettre au courant des divers arguments et méthodes qui ont été utilisés pour instaurer et communiquer la confiance dans la sûreté, et de prendre directement connaissance des expériences acquérir par les autres organisations en matière d'élaboration et de communication des arguments visant à susciter la confiance.

4.2 Comparaison des résultats de l'IPAG-3 à ceux de l'IPAG-1 et de l'IPAG-2, de même qu'avec le document de l'AEN sur la confiance

Un certain nombre des sujets et problèmes examinés dans l'IPAG-3, avaient aussi été abordés au cours des deux phases précédentes de l'IPAG [AEN, 1997 et AEN, 200-a]. Il s'agit de la notion de barrières multiples, des problèmes relatifs à la biosphère, et du recours à l'argumentation multiple, aux analogues naturels et à la paléohydrogéologie dans l'élaboration du dossier de sûreté. Les observations et recommandations de l'IPAG-3 sur ces sujets prolongent et approfondissent les résultats de l'IPAG-1 et de l'IPAG-2.

L'IPAG-3 est cependant parvenu à la conclusion que l'une des recommandations de l'IPAG-2 relative à la notion de barrières multiples ne serait pas aisément réalisable. L'IPAG-2 a recommandé de définir le concept du système à barrières multiples en s'inspirant du sens littéral de « plus d'une barrière » et intègrent la notion selon laquelle les diverses barrières passives contribuent chacune à la sûreté et interviennent ensemble de façon complémentaire en assurant un certain degré de redondance. Les participants de l'IPAG-3 ont observé l'existence de différences culturelles dans la manière de considérer le concept et par là-même la définition exacte de ce concept variera d'un pays à un autre. Par exemple, la plupart des pays considèrent qu'une barrière est un obstacle matériel, s'agissant d'une barrière ouvragée ou de la géosphère. Cependant, certains pays étendent la définition de manière à inclure les processus physiques et chimiques qui empêchent ou retardent la libération ou la migration des radionucléides. À ce titre, l'IPAG-3 recommande aux exploitants clairement dans leur dossier de sûreté ce qu'ils entendent par le concept de barrières multiples, notamment les éventuelles exigences fonctionnelles applicables à leur système à barrières multiples. Comme cela est indiqué dans la section 3.1, on dispose de méthodes et de techniques pour évaluer l'efficacité d'un système à barrières multiples.

Le document de l'AEN sur la construction de la confiance [AEN, 1999] propose un cadre pour décrire les divers concepts liés à l'instauration de la confiance dans la sûreté à long terme des dépôts géologiques profonds, et les méthodes utilisées pour évaluer, renforcer et communiquer cette confiance. Le questionnaire relatif à l'IPAG-3 contenait un certain nombre de questions ayant pour but de trouver des exemples pour confirmer les concepts et les démarches examinés dans le document sur la confiance. La variété des types d'arguments visant à gagner la confiance, qui ont été recensés dans les divers dossiers de sûreté étudiés dans l'IPAG-3, illustre la notion globale d'instauration de la confiance telle que décrite.de l'AEN (AEN99) décrite dans le document. En particulier, comme cela est récapitulé dans le tableau 2, des arguments visant à asseoir la confiance ont été identifiés pour différents aspects du système de stockage géographique profondes et son évaluation de la sûreté à long terme associée. Trouver des exemples d'instauration de la confiance par le biais de processus itératifs d'évaluation s'est avéré beaucoup plus délicat, car peu de programmes ont donné lieu à suffisamment de cycles d'évaluation visant une installation ou un concept pour illustrer pleinement ce processus. De même, en ce qui concerne la robustesse, le document sur la confiance proposait de classer les arguments en la matière comme ayant trait soit à la « robustesse intrinsèque », soit à la « robustesse technique ». Comme cela est exposé dans la section A5 de l'Annexe A, un certain nombre d'exemples de robustesse des systèmes ont été identifiés ; cependant, il n'a pas été simple de classer ces exemples parmi ces termes robustesses « intrinsèque » ou « technique ». En tant que telle, la distinction entre la robustesse « intrinsèque » et « technique » peut ne pas être suffisante pour justifier actuellement l'emploi de deux termes différents.

Dans l'ensemble, les enseignements de l'IPAG-3 et ceux des travaux antérieurs, dénotent une nette tendance des programmes à se tourner vers une stratégie globale en vue de gagner et de communiquer la confiance. Le document de l'AEN sur la confiance était orienté vers l'élaboration de stratégies plus intégrées. La poursuite de l'élaboration de ces stratégies en vue de gérer les incertitudes et de susciter la confiance dans la sûreté à long terme, constituera une tâche importante du Groupe d'intégration pour le dossier de sûreté (IGSC). Les examens des études de sûreté en cours futures pour le compte des différentes parties prenantes permettront de s'en faire une idée pratique.

5. RÉFÉRENCES

IAEA, 1996, Clearance Levels for Radionuclides in Solid Materials – Application of Exemption Principles – Interim Report for Comments, [Niveaux de libérations relatifs aux radionucléides renfermés dans des matériaux solides – Application des principes d'exemption – Rapport provisoire soumis pour commentaires], Agence internationale de l'énergie atomique, Vienne, janvier 1996.

AEN, 1997, Lessons learnt from Ten Performance Assessment Studies – Enseignements tirés de dix études d'évaluation des performances, Agence de l'OCDE pour l'énergie nucléaire, Paris, 1997.

AEN, 1999, Confidence in Long-term Safety of Deep Geological Repositories – Its development and communication, Confiance dans la sûreté à long terme des dépôts géologiques profonds – moyens de l'instaurer et de la communiquer, Agence de l'OCDE pour l'énergie nucléaire, Paris, 1999.

AEN-2000-a, Évaluation des dépôts géologiques profonds dans un contexte réglementaire – Enseignements tirés, Agence de l'OCDE pour l'énergie nucléaire, Paris, 2000.

AEN, 2000-b, Stakeholder Confidence and Radioactive Waste Disposal, La confiance des parties prenantes et l'évacuation des déchets radioactifs, Compte rendu d'un séminaire, Paris, France, 28-31 août 2000, Agence de l'OCDE pour l'énergie nucléaire.

ACRONYMES

EIS :	Déclaration d'incidences sur l'environnement
FEPs :	Caractéristiques, événements et processus
FSC :	Forum sur la confiance des parties prenantes
IGSC :	Groupe d'intégration pour le dossier de sûreté
EIP(s) :	Évaluations intégrées des performances
IPAG :	Groupe de travail sur les évaluations intégrées des performances des dépôts profonds
PA :	Évaluation des performances
PAAG :	Groupe consultatif sur l'évaluation des performances des systèmes d'évacuation des déchets radioactifs
RWMC :	Comité de la gestion des déchets radioactifs
SEDE :	Groupe de coordination sur l'évaluation des sites et la conception des expériences pour l'évacuation des déchets radioactifs

ALSO AVAILABLE

NEA Publications of General Interest

2000 Annual Report (2001) *Free: paper or Web.*

NEA News
ISSN 1605-9581 Yearly subscription: € 37 US$ 45 GBP 26 ¥ 4 800

NEA Brochure *Free: paper or Web.*

Geologic Disposal of Radioactive Waste in Perspective (2000)
ISBN 92-64-18425-2 Price: € 20 US$ 20 GBP 12 ¥ 2 050

Radioactive Waste Management

Radionuclide Retention in Geologic Media (2002)
ISBN 92-64-19695-1 Price: € 55 US$ 49 £ 34 ¥ 5 500

Using Thermodynamic Sorption Models for Guiding Radioelement Distribution Coefficient (KD) Investigations – A Status Report (2001)
ISBN 92-64-18679-4 Price: € 50 US$ 45 £ 31 ¥ 5 050

Gas Generation and Migration in Radioactive Waste Disposal – Safety-relevant Issues (2001)
ISBN 92-64-18672-7 Price: € 45 US$ 39 £ 27 ¥ 4 300

Confidence in Models of Radionuclide Transport for Site-specific Assessment (2001)
ISBN 92-64-18620-4 Price: € 96 US$ 84 £ 58 ¥ 9 100

Porewater Extraction from Argillaceous Rocks for Geochemical Characterisation (2000)
ISBN 92-64-17181-9 Price: € 61 US$ 60 GBP 37 ¥ 6 350

Regulatory Reviews of Assessments of Deep Geological Repositories – Lessons Learnt (2000)
ISBN 92-64-05886-9 Price: € 34 US$ 32 GBP 20 ¥ 3 400

Nuclear Waste Bulletin – Update on Waste Management Policies and Programmes, No. 14, 2000 Edition (2001) ISBN 92-64-18461-9 *Free: paper or Web.*

Reversibility and Retrievability in Geologic Disposal of Radioactive Waste (2001)
ISBN 92-64-18471-6 *Free: paper or Web.*

The Role of Underground Laboratories in Nuclear Waste Disposal Programmes (2001)
ISBN 92-64-18472-4 *Free: paper or Web.*

Strategic Areas in Radioactive Waste Management – The Viewpoint and Work Orientations of the NEA Radioactive Waste Management Committee (2000) *Free: paper or Web.*

Stakeholder Confidence and Radioactive Waste Disposal (2000)
ISBN 92-64-18277-2 *Free: paper or Web.*

GEOTRAP: Radionuclide Migration in Geologic Heterogeneous Media – Summary of Accomplishments (2002) ISBN 92-64-18479-1 *Free: paper or Web.*

An International Peer Review of the Yucca Mountain Project – Total System Performance Assessment for the Site Recommendation (TSPA-SR) (2002) – ISBN 92-64-18477-5 *Free: paper or Web.*

Order form on reverse side.

ORDER FORM

OECD Nuclear Energy Agency, 12 boulevard des Iles, F-92130 Issy-les-Moulineaux, France
Tel. 33 (0)1 45 24 10 15, Fax 33 (0)1 45 24 11 10, E-mail: nea@nea.fr, Internet: www.nea.fr

Qty	Title	ISBN	Price	Amount
			Total	

Charge my credit card ☐ VISA ☐ Mastercard ☐ Eurocard ☐ American Express

Card No.	Expiration date	Signature
Name		
Address	Country	
Telephone	Fax	
E-mail		

OECD PUBLICATION, 2, rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE
(66 2002 09 3 P) ISBN 92-64-09782-1 – No. 52510 2002