Radioactive Waste Management

# SYMPOSIUM

# SAFETY CASES FOR THE DEEP DISPOSAL OF RADIOACTIVE WASTE: WHERE DO WE STAND?

## COMPILATION OF ABSTRACTS

Paris La Défense, France
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# Session II a

## THE INTERNATIONAL EVOLUTION

# NEA: THE SAFETY CASE CONCEPT, ITS HISTORY AND PURPOSES

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The current concept of a safety case has evolved gradually over the past two decades with a notable acceleration in the mid-90's. Recent safety cases recognise that (1) repository development proceeds in stages and safety studies are needed not for the purpose of predicting performance per se but to inform decision-making at each development stage; (2) decision-making does not require perfect prediction of system evolution, but rather sufficient confidence that possible future outcomes are bounded, based on the quality of the information and the robustness of the analysis for the decision at hand. There is now general recognition that, even though a safety case is founded on scientific and engineering principles, it cannot be validated in the normal scientific sense, and that long-term safety can be illustrated but never truly demonstrated. Since these important considerations became an integral part of the culture of national programmes, greater emphasis has been given to the quality of underlying knowledge and system understanding vis-à-vis relying largely on complex numerical computations. Accordingly, national programmes have been relying increasingly on multidisciplinary teams of experts. Management tools have been developed to ensure that all voices are heard and that bias is eliminated to the greatest extent possible. Important methodological evolutions have also taken place: (a) whereas the approach once was to develop project-specific sets of FEPs upon which to create assessment cases, the latter are now derived from an evaluation of the underlying knowledge basis; (b) building upon the multi-barrier concept, the new concept of safety functions has arisen and is widely used; (c) does and risk indicators are now typically accompanied by other indicators of performance and safety; (e) traceability has greatly improved through documentation, and the same holds true for (e) transparency, whereby the description and understanding of the system is distinguished from the evaluation of its performance; (f) quality management has become more important. The safety case concept was first elaborated within the NEA in the late 90's. The ensuing confidence document (1999) is at the basis of much of

the work that followed thereafter, which included the creation of the Integration Group for the Safety Case (IGSC) and culminated with the publication of the Safety Case brochure of 2004 and the joint IAEA-NEA Safety Requirements Standard of 2005. The ideas were also absorbed in other national and international programmes, and we are fortunate nowadays to have a shared vocabulary that allows specialists to better communicate on the various aspects of the safety case. The Safety Case concept will continue to evolve through discussion amongst all interested parties, and in particular through the regulator-implementer dialogue. Topics on the top of the agenda include (a) BAT, optimisation (and the relationship between design and site), and the very concept of safety; (b) how to address the very long term in view of the hazard that the waste continue to pose; (c) organisational issues (do we know what safety culture is?); (d) operational safety, (e) continued methodology development, and (f) further clarification of the concepts of confidence and confidence statements.

# ICRP: THE EVOLUTION OF THOUGHTS FROM THE ICRP 46 CONCEPT OF POTENTIAL EXPOSURE

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The paper emphasizes the on-going evolution of ICRP system, the main ICRP publications on potential exposure and waste disposal and finally, more specifically the recommendations on solid waste disposal in publication 81.

Application of potential exposure concept to exposures that could occur far in the future is a particular difficult issue because of the level of uncertainties associated with the assessment of the probabilities of the events leading to the exposures as well as with the evaluation of the doses to the populations.

The general orientations of the new ICRP recommendations aimed at a less complex system and proposing a simple scale of source related constraints or reference levels and focusing on a judgmental approach of optimisation, is better suited to such an issue.

ICRP 46, although too theoretical in its approach, was a kind of pioneer by applying optimisation to probabilistic events and setting upper levels to the process. In the same way, ICRP 81, in recommending a disaggregated and judgmental approach of optimisation based on dose and probability estimations to be compared with dose or risk constraints is in line with the future new recommendations.

# THE EVOLUTION OF SAFETY STANDARDS (WS-R-4) AND REQUIREMENTS IN RESPECT OF THE SAFETY CASE

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In terms of its statute the IAEA is mandated to develop safety standards for nuclear, radiation, radioactive waste and transport safety, and to provide for their use and application. At the 2000 Cordoba Conference on the safety of radioactive waste management, it was concluded that, in view of foreseen developments in the area, work should commence on the development of safety standards for geological disposal. Work commenced on a Safety Requirements standard in 2001 and was concluded in 2005 with the adoption of the standard by the IAEA Board of Governors and the Steering Committee of the OECD/NEA, co-sponsors of the standard. The standard sets down protection criteria together with a comprehensive set of discrete requirements for the planning, development, operation and closure of geological disposal facilities. Specific requirements are included regarding the preparation of the safety case and safety assessment, the scope of the safety case and safety assessment and concerning documentation of the safety case and safety assessment. The paper elaborates the requirements, provides some background to their development and discusses activities of the IAEA related to their use and application.

# LESSONS LEARNT FROM 25 YEARS OF EXPERIENCE WITH PA/SA EXERCISES IN THE EUROPEAN UNION

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Over the past 25 years the methodology for assessing the safety of deep geological disposal of radioactive waste has evolved focussing particularly on vitrified high level waste and spent fuel. During this time the European Union has successfully initiated progress through a long series of research projects. In the early years it was shown that safe disposal of all types of radioactive waste in any of the formations considered can be achieved, irrespective of the type of radioactive waste emplaced and the radionuclide inventories. Also it was observed that common methodological approaches allow better control of numerical results of integrated PA models which increases understanding of system behaviour and contributes to build confidence in the results.

The last years have witnessed a strong move towards more sophisticated modelling approaches on the process level regarding effects and processes in the near-field, the geosphere, and the biosphere, respectively. Significant advances have been achieved in the abstraction of these processes to integrated PA models. Besides a number of safety and performance indicators were identified and systematically tested in order to assess their suitability and applicability in a safety case. The major lessons learnt from these projects will be presented. Apart from national waste management organisations these projects involved to an increasing extent research institutions as well as regulators and technical safety organisations. A growing number of countries participate in such projects which contribute to the development of a common European understanding of

performance assessment approaches and methodologies for geological disposal of radioactive wastes.

# Session II b

## THE NATIONAL EVOLUTION

# A COMPARISON OF NATIONAL DOSE AND RISK CRITERIA FOR DEEP DISPOSAL OF LONG-LIVED RADIOACTIVE WASTE

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The Regulators' Forum of the NEA's Radioactive Waste Management Committee undertook, as one of its first actions after it was formed in 1999, a comparative study of the regulation of proposed repositories for long-lived high-level waste in member countries. One particular aspect of this study was a comparison of the dose and risk criteria proposed or used in member countries, and of whether and how these criteria depended on the time scale.

The first phase of this study revealed that while, broadly speaking, the criteria used in most countries were generally similar, when these criteria were expressed in comparable units the entire range spanned was fairly broad (about two orders of magnitude). The differences are particularly evident when the criteria at long time scales (beyond $10^3$-$10^4$ years) are compared.

This paper presents the results of this study in tabular form, together with a discussion of some of the possible underlying reasons for the differences between national criteria and of their significance. Work is ongoing to investigate these reasons with the aim of developing a common understanding of the fundamental objectives of the regulation of disposal in order to facilitate discussion of comparative approaches.

1. Work performed on behalf of the NEA Secretariat (C. Pescatore)

# HOW HAS THE SAFETY CASE EVOLVED IN THE SWISS NATIONAL PROGRAMME?

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In this paper the evolution of the safety case (concept and application) in the Swiss national programme is discussed and illustrated with a number of specific examples for which the development of selected aspects of a safety case is tracked making use of “example safety cases” compiled at various points in time. These example safety cases are (i) Project Gewähr – HLW part (1985), (ii) the Kristallin-I study (1994) and (iii) Project Entsorgungsnachweis (2002).

# PROPOSED AMENDMENTS TO THE ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR YUCCA MOUNTAIN, NEVADA

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The Environmental Protection Agency (EPA) proposed amendments to its radiation protection standards for the potential spent nuclear fuel and high-level radioactive waste disposal system in Yucca Mountain, Nevada, on 22 August 2005. The original standards are found in Part 197 of Title 40 of the Code of Federal Regulations (40 CFR Part 197). The Energy Policy Act of 1992 directed, and gave the authority to, EPA to take this action based upon input from the National Academy of Sciences (NAS). The final original standards were published in the *Federal Register* (66 FR 32073) on 13 June 2001. In July 2004, a Federal court remanded part of the standards to EPA for reconsideration.

The 40 CFR Part 197 standards, as issued in 2001, have four major parts: (1) individual-protection during storage activities; (2) individual-protection following closure of the repository; (3) human-intrusion; and (4) ground-water protection. The storage standard is 150 microsieverts (μSv) (15 mrem) annual committed effective dose equivalent (CEDE) to any member of the general public. The disposal standards are: (1) 150 μSv (15 mrem) annual CEDE for the reasonably maximally exposed individual (RMEI) for 10 000 years after disposal; (2) 150 μSv (15 mrem) annual CEDE received by the RMEI within 10 000 years after disposal as a result of human intrusion; and (3) the levels of radionuclides in the ground water cannot cause annual individual doses to exceed: (1) 40 μSv (4 mrem) per year from beta and gamma emitters or (2) 5 picocuries per liter (pCi/L) of radium-226 and -228 or 15 pCi/L of gross alpha activity. There were also requirements related to the post-10,000-year period, the basis of compliance judgments, and performance assessments.

On August 22, 2005, in response to a federal Court decision, the Agency proposed amendments to this standard that would retain the individual-protection standard established in the 2001 standards, up to 10 000 years. In addition, the compliance period for the individual-protection and human-intrusion standards would be increased to 1 million years and the annual CEDE

limit between 10 000 and 1 million years would be 3.5 mSv (350 mrem). There are also proposed requirements for the way performance assessments will be conducted. Finally, the dose calculation methodology would be updated to an ICRP 60 and 72 basis instead of ICRP 26 and 30.

The comment period on the proposed amendments ended 21 November 2005. The Agency is analyzing the comments and will publish its responses when issuing the final standards, currently estimated for early 2007. The proposed standards and the support documents are available at [http://www.epa.gov/radiation/yucca/index.html.] The docket containing all of the comments is under Docket ID EPA-HQ-OAR-2005-0083 at: [http://www.regulations.gov.]

# Session III a

## APPROACHES TO ACHIEVING SAFETY

# APPLICATION OF SAFETY CASE CONCEPT IN PRACTICE PRELIMINARY FINDINGS FROM THE NEA INTESC INITIATIVE

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During 2006 NEA issued a questionnaire on “INTernational Experiences in Safety Cases” (INTESC). Answers have been received from 15 organisations representing both implementing organisations and regulatory authorities in nine countries. NEA is currently compiling the answers entailing a detailed review, sorting, and analysis of results to further refine the themes, trends, significant advancements, points of divergence, and key challenges. All responding programmes are preparing extensive safety cases (or preliminary ones) in line with most of the elements of a safety case suggested by the NEA Safety Case brochure. Judging from the regulatory responses, such an ambition level is also required according to regulations. Overall, there are similar approaches and attitudes in different programs and similar concerns expressed from the participating regulators. Implementers appear to address issues raised by regulators. However, there are some important examples of differences in use or in interpretation and there are some elements of real life safety cases not covered by the brochure. Furthermore, there is substantial overlap between several of the elements listed in the brochure and some further definition of the elements and terminology may be helpful to clarify the actual differences and similarities in safety cases.

# BÁTAAPÁTI REPOSITORY - EVOLUTION OF THE SAFETY CASE

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The Hungarian programme for the development of a new repository for L/ILW has its roots in the 1980s. Today underground investigations are in progress in tunnels being constructed in granitic rock towards the potential location of the repository in the finally selected site area. This is near Bátaapáti.

It is almost inevitable that the site-specific information which is available initially for a deep geological repository will be extremely limited. This was certainly the case in Hungary and this deficiency presents a considerable challenge in the context of establishing a safety case for use in making the important decisions on site selection and on finance which are necessary in the early part of such a repository programme.

In the paper the history to date of the evolution of the safety case for the new L/ILW repository in Hungary is described. This description includes the institutional aspects, such as the increasing definition of the organizational responsibilities in the early stages of the programme, the use of external peer review, and the ongoing emphasis on the quality management of the investigations and of the design activities. Information is presented on the progress of the site investigations during the programme period and of the influence of the resulting improvement in the knowledge base on the increasingly site-specific conceptual models of the geosphere which formed the basis of the successive safety analyses. Such analyses will be used in licensing to demonstrate the compliance with the Hungarian safety regulations.

# AN ITERATIVE APPROACH TO ACHIEVING SAFETY: APPLICATION IN THE DOSSIER 2005 ARGILE

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The "Dossier 2005 Argile" presents the feasibility assessment – with regard to the technical capacity to accommodate all wastes, to reversibility, and to safety – of radioactive waste disposal in a clay formation studied at the Meuse/Haute-Marne URL. It was built upon an iterative approach between site characterization, design, modelling, and safety analysis, in which two principles always guided the elaboration of the safety case:

- Robustness – repository components must maintain their functionality given reasonable solicitations, taking into account uncertainties on the nature and level of these solicitations;
- Demonstrability – the safety must be verified without requiring complex demonstrations, but based on multiple lines of evidence/argument (numerical simulation, qualitative arguments such as use of natural analogues, experiments and technological demonstrators).

In that respect, key elements in the development of a coherent post-closure safety case are: (i) the functional analysis to determine the safety functions and requirements and the related technical architecture and design based on current industrial experience; (ii) the Phenomenological Analysis of Repository Situations providing a good scientific understanding based on surface and underground laboratory experiments, (iii) the qualitative safety analysis managing uncertainties and the quantitative assessment of scenarios including sensitivity analysis.

The aim of this article is to present the methods that Andra implemented in the context of Dossier 2005 Argile.

# DEVELOPING A SAFETY CASE FOR ONTARIO POWER GENERATION'S L&ILW DEEP GEOLOGIC REPOSITORY

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Ontario Power Generation is proposing to build a Deep Geologic Repository (DGR) for low and intermediate level radioactive waste at the Bruce Nuclear Site, Tiverton, Ontario, Canada. The DGR concept envisions a geologic repository excavated at a nominal depth of 500 to 700 m below ground surface within a horizontally bedded sequence of sedimentary rock formations underlying the site. The purpose of the current iteration of the Safety Case is to help guide the planning for site characterisation, engineering design and safety assessment by providing a common understanding of what needs to be demonstrated within the Safety Case for the Environmental Assessment approval phase. This Safety Case is based on conceptual design information, general knowledge of the geology at the site, and scoping safety assessment calculations, and will be updated as more detailed information becomes available.

The proposed safety strategy, consistent with the Nuclear Energy Agency's Safety Case approach, is described. Key elements of the strategy relevant to the Safety Case are stepwise planning and implementation, integration of technical work in support of the Safety Case, iterative approach for development of technical studies, emphasis on the geosphere barrier (e.g. low permeability, homogeneity and predictability), understanding of the site and its evolution, simple robust arguments supported by multiple lines of reasoning including more detailed calculations, analysis of uncertainty, consistency with international practice, and use of national and international experiences with similar facilities. The proposed Safety Case main arguments and evidence are summarized.

# DEVELOPMENT OF A METHODOLOGY FOR AN ENVIRONMENTAL SAFETY CASE IN THE UK

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The recent UK Government review of radioactive waste management policy has reaffirmed geological disposal as the preferred long-term management option. However, a key issue for stakeholders is the demonstration of confidence in the long-term safety of this option.

Assurance of the safety of a concept cannot be made convincingly solely on the basis of numerical calculations that span timescales beyond those where the results can be tested experimentally. Also, many stakeholders will need to take detailed mathematical analyses on trust. Nirex is therefore planning to broaden the scope of its safety analysis, making greater use of qualitative safety arguments in addition to assessments pertaining to numerical regulatory criteria. The safety arguments and analyses will be presented in an Environmental Safety Case (ESC), with the primary objective of building confidence in the safety of deep geological disposal.

The ESC will draw on evidence from a wide range of sources, including fundamental arguments for the isolation and containment potential of geological systems, comparisons with natural and anthropogenic analogues and complementary indicators in order to make the safety case.

This paper will explain, giving examples, how a wide variety of more qualitative safety arguments can be integrated into the safety case. It will discuss ways of presenting these arguments alongside the more familiar numerical analyses to build a robust ESC, aimed at building confidence for a variety of stakeholder audiences. It will also propose a hierarchical documentation structure that provides traceability of information and the flexibility to evolve and develop throughout the different stages of a repository stepwise decision-making programme.

# STRATEGY FOR SAFETY CASE DEVELOPMENT: IMPACT OF A VOLUNTEERING APPROACH TO SITING A JAPANESE HLW REPOSITORY

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NUMO's strategy for safety case development is constrained by a staged siting approach, which has been initiated by a call for volunteer municipalities to host the HLW repository. For each site, the safety case is an important factor to be considered at the selection steps – which narrow down towards the preferred repository location. This is particularly challenging, however, as every site requires a tailored repository concept, with associated performance assessment and an individual site evaluation programme – all of which evolve with gradually increasing understanding of the host environment. In order to maintain flexibility without losing focus, NUMO has developed a formalised tailoring procedure, termed the NUMO Structured Approach (NSA). The NSA guides the interaction of the key site characterisation, repository design and performance assessment groups and is facilitated by tools to help the decision-making associated with the tailoring process (e.g. a requirements management system) and with comparison of siting and design options (e.g. multi-attribute analysis). Pragmatically, the post-closure safety case will initially emphasise near-field processes and a robust engineering barrier system, considering the limited geological information at early stages. This will be complemented by a more realistic assessment of total system performance, as needed to compare options. In addition, efforts to rigorously assess operational phase safety and the practicality of assuring quality of the constructed engineered barriers are components of the total safety case which are receiving particular attention now, as they may better discriminate between sites while information is still limited.

# THE CANADIAN NUCLEAR REGULATORY PROCESS AND USE OF THE SAFETY CASE FOR DEMONSTRATING THE LONG TERM SAFETY OF RADIOACTIVE WASTE

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The Canadian Nuclear Safety Commission (CNSC) regulates the use of nuclear energy and materials in Canada to protect health, safety, security and the environment and to respect Canada's international commitments on the peaceful use of nuclear energy. In this respect, the CNSC makes regulatory decisions on behalf of Canadian society. This paper describes how the main elements of the safety case form an integral part of the licensing decisions made by the CNSC. The components of a safety case are a fundamental part of the information that the CNSC requires in support of a licence application or a pre-licensing environmental assessment. The use of the safety case is discussed in relation to the CNSC's open and transparent licensing process, where affected parties and members of the public are given the opportunity to be heard before the Commission through a public hearing process.

# THE ONDRAF/NIRAS SAFETY STRATEGY FOR THE DISPOSAL OF CATEGORY B&C WASTES

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ONDRAF/NIRAS has formulated a safety strategy for the disposal of B&C wastes that describes the process for developing (i) a concept and design for the geological disposal of these wastes and (ii) the evidence and arguments to show that these are both safe and feasible to implement as planned.

A generic concept for disposal is developed first; it refers only to broad system components and their functions, and not e.g. to specific materials and dimensions. Consideration is given to what are the essential elements of the repository and its environment, and strategic choices are made concerning what these elements will need to do in order to satisfy the primary objective of long-term safety, given programme boundary conditions (e.g. available geological settings) and guided by relevant principles.

An engineering design is then developed iteratively in a process involving, at each stage:

1. consideration of the design options available to implement the strategic choices made in concept development;
2. consideration of the possibilities for implementing the design options; and
3. systematic development and evaluation of a structured set of safety and feasibility statements for a given design option and set of implementation procedures.

This last step consists of:

a. considering, in a top-down fashion, what statements will be made regarding the long-term safety and feasibility of the disposal system as a whole and of individual system components as part of a safety and feasibility case; and

b. considering, from the bottom up, whether the support that is available for these statements from the assessment basis and from safety assessments gives sufficient confidence (in the view of ONDRAF/NIRAS) to justify a positive decision to proceed to the next programme stage.

These last two outputs in particular are key elements of the safety and feasibility case for a given concept and design. They also provide guidance on R&D and demonstration priorities to enhance the design and the assessment basis for future project stages (statements should develop from hypotheses to well-supported claims as a programme progresses).

The paper will present a preliminary, structured set of safety and feasibility statements for a repository for B&C wastes, and an systematic evaluation of these statements in terms of (i) how well supported a statement needs to be, or how critical the statement is, in the context of the current programme stage and (ii) what is the level of support that is currently available.

# DEVELOPING AN ADVANCED SAFETY CONCEPT FOR AN HLW REPOSITORY IN SALT ROCK

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Preliminary Total Performance Assessments for HLW repositories in salt rock were performed within the framework of German R&D projects at the end of the 1980s and in the first half of the 1990s. In the meantime, several remarkable developments improved the basis for developing an advanced safety case:

- Surface and particularly underground exploration results of the Gorleben salt dome are available and provide an improved understanding of the geological system and corresponding processes.
- In the course of developing the closure concepts for the Morsleben Repository and Asse Mine, major progress was made regarding the design and performance proof of engineered barriers, in particular shaft and drift seals.
- Advanced tools have been developed and the knowledge base for assessing the consequences of radionuclide release in case of disturbed repository evolution has significantly improved.
- Contrary to the existing German safety criteria, the ongoing revision of these criteria intends to classify possible repository evolution incidents into scenarios with high and low probabilities.

In view of these changes, DBE TECHNOLOGY GmbH, BGR and GRS are developing and testing an advanced safety concept within a joint R&D project in order to identify the major needs for further R&D work. Whilst former safety assessment approaches for HLW repositories in salt rock used a conservative, even hypothetical, release scenario in order to show the compliance with dose constraints, the recent safety concept focuses on proving the safe enclosure without radionuclide release if the repository evolution remains undisturbed. Release scenarios are considered in the case of disturbed evolution only. This approach is considered to be more appropriate for a salt rock repository and takes advantage of its specific properties.

In this context, special attention is given to the proof of integrity (sufficient tightness) of the multi-barrier system, comprised mainly of the host rock as the main geological barrier and the engineered geotechnical barriers. The approach also focuses on appropriate scenario analyses that allow the identification and assessment of remaining radionuclide release scenarios which cannot be ruled out.

Moreover, another emphasis of the project is to check in detail the physical and technical feasibility of all assumptions made for the safety assessment, since the technical feasibility is deemed an essential precondition for a safe repository not only in rock salt.

# Session III b

## THE SCIENTIFIC AND TECHNICAL BASIS FOR ASSESSING SAFETY

# THE PHENOMENOLOGICAL ANALYSIS OF REPOSITORY SITUATIONS (PARS) – APPLICATION WITHIN THE DOSSIER 2005 ARGILE (MEUSE/HAUTE MARNE SITE)

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Phenomenological Analysis of Repository Situations of Storage (PARS.) aims at identifying the phenomena which occur during the evolution of the repository from the beginning of its construction until times in connection with the decrease of the radioactivity of waste i.e. one million years. The complexity of the system leads to segment this evolution in time and space through "situations". A repository "situation" is a unit of this segmentation that describes a phenomenological state of the disposal and/or its geological environment at one specific stage of the evolution of the repository. The input data to PARS are the design of the repository and the scientific and technological knowledge available.

For each situation, in a systematic way, analysis includes: the identification of thermal, hydraulic, chemical, mechanical and radiological phenomena; the description of the sequence of the phenomena ("processes") and their couplings; the identification of radionuclides release by waste packages and of their pathways from the repository to the biosphere. The results of this analysis are presented in "cards of situation". The description of each situation is provided with a synthesis of the phenomenological state, specifying the dominant phenomena and the uncertainties.

The conceptual models of the repository situations constitute successive and specific pictures of the phenomenological evolution of the repository and its geological environment. They constitute both input data to modelling and a support for the definition of the program of observation within the framework of the reversibility assessment. It is thus a reference framework for the safety analyses, in particular by identifying uncertainties remaining at the stage of the analysis.

# KNOWLEDGE MANAGEMENT: THE CORNERSTONE OF A 21ST CENTURY SAFETY CASE

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The safety case for a radioactive waste repository involves many complex, multi-disciplinary issues; these must be summarised in a comprehensive and concise manner, with links to all supporting information. The safety case can thus be considered an edifice built on structured knowledge. Knowledge is defined here in the very widest sense; including all of the information underpinning a repository project. Knowledge management covers all aspects of the development, integration, quality assurance, communication and maintenance/archiving of such knowledge. When seen from this perspective, the exponential expansion of the knowledge base represents a little-discussed challenge to safety case development. Indeed, knowledge production rates in this area are rapidly reaching, if not already surpassing, the limits of traditional management methods.

This problem has been recognised in Japan and thus a project has been initiated to develop a “next generation” knowledge management system (KMS). This will utilise advanced electronic information management technology to handle the vast quantity of material involved. Autonomic systems will perform many of the information processing functions, helping ensure that required knowledge is accessible to all stakeholders and that gaps can be identified and supporting R&D prioritised. In a departure from conventional structuring by technical discipline, the prototype KMS utilises a safety case structure. This should facilitate use of the core of “neutral” scientific and technical knowledge by both the implementer and the regulator. Flexibility is built into the system, to allow it to be restructured to match the user’s needs or even interfaced directly to a formal requirements management system.

# SAFETY FUNCTIONS AND SAFETY FUNCTION INDICATORS – KEY ELEMENTS IN SKB'S METHODOLOGY FOR ASSESSING LONG-TERM SAFETY OF A KBS-3 REPOSITORY

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The application of so called safety function indicators in SKB's safety assessment of a KBS-3 repository for spent nuclear fuel is presented. Isolation and retardation are the two main safety functions of the KBS-3 concept. In order to quantitatively evaluate safety on a sub-system level, these functions need to be differentiated, associated with quantitative measures and, where possible, with quantitative criteria relating to the fulfilment of the safety functions. A safety function is defined as a role through which a repository component contributes to safety. A safety function indicator is a measurable or calculable property of a repository component that allows quantitative evaluation of a safety function. A safety function indicator criterion is a quantitative limit such that if the criterion is fulfilled, the corresponding safety function is upheld. The safety functions and their associated indicators and criteria developed for the KBS-3 repository are primarily related to the isolating potential and to physical states of the canister and the clay buffer surrounding the canister. They are thus not directly related to release rates of radionuclides. The paper also describes how the concepts introduced *i*) aid in focussing the assessment on critical, safety related issues, *ii*) provide a framework for the accounting of safety throughout the different time frames of the assessment and *iii*) provide key information in the selection of scenarios for the safety assessment.

# THE ROLE OF STRUCTURAL RELIABILITY OF GEOTECHNICAL BARRIERS OF HLW/SF REPOSITORY IN SALT ROCK WITHIN THE SAFETY CASE

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Regarding a final repository in salt rock, geotechnical barriers are placed parallel to the impermeable geological rock salt barrier to seal the access tunnels and shafts in order to isolate the disposal areas from the biosphere. Geotechnical barriers are shaft and drift seals, and in some cases borehole seals. Their function is to efficiently seal the man-made pathways directly after repository closure. As the proof of structural reliability of geotechnical barriers is fundamental to assess the long-term safety of an HLW/SF final repository in salt rock, the present status of the proof of structural reliability of geotechnical barriers was reviewed. The result of the review process is given below.

# UNDERSTANDING THE EVOLUTION OF THE REPOSITORY AND THE OLKILUOTO SITE

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Posiva's Safety Case is organised in a portfolio including ten main reports: Site, Spent Fuel Characteristics and Inventories, Canister Design, Repository Design, Process, Evolution of the Repository and the Site, Biosphere Assessment, Radionuclide Transport, Complementary Evaluations of Safety, and Summary. This portfolio constitutes the basis of the Preliminary Safety Assessment Report, which will be presented to the authorities in 2012 as part of the repository construction license application. The Evolution report, which is the focus of this paper, is the main advance in the Safety Case portfolio since the implementation of the Safety Case plan in 2005. The report provides the status of current knowledge with respect to the evolution of the site and the engineered barrier system and highlights areas where better understanding is needed.

# MAKING THE POST-CLOSURE SAFETY CASE FOR THE PROPOSED YUCCA MOUNTAIN REPOSITORY

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Office of Civilian Radioactive Waste Management, United States Department of Energy (DOE), USA

The United States Department of Energy (DOE) is preparing to submit an application to the United States Nuclear Regulatory Commission (NRC) in June 2008 for authorization to construct the proposed Yucca Mountain repository for high-level radioactive waste and spent nuclear fuel. The DOE's license application will provide the basis for a safety case consistent with the guidelines provided by the International Atomic Energy Agency; including both results of a quantitative safety assessment and comprehensive supporting information that will allow the NRC to make an informed decision regarding the licensing of the disposal facility. Although information presented in this paper is limited to post-closure performance of the repository, the safety case presented in the license application will include systematic analysis of hazards, integration of arguments and evidence that support the finding of safety, and an evaluation of uncertainties and a discussion of the basis for confidence to move forward while acknowledging uncertainty for both pre-closure and post-closure analyses. Confidence in the post-closure safety case will come from both technical and institutional bases. Technical bases for confidence include reliance on multiple barriers that includes both natural and engineered systems to isolate the waste, detailed scientific characterization and modeling of these barriers, and a system-level safety assessment including a full treatment of uncertainty. Confidence is enhanced by thorough internal checking and analysis, peer review, and corroboration with analogue information where available. Institutional bases for confidence include a rigorous quality assurance program, implementation of active and passive controls at the site, and a strong performance confirmation program that will challenge data and models underlying the safety assessment.

# Session III c

## EVALUATING AND DOCUMENTING THE CONFIDENCE IN SAFETY

# ELEMENTS OF THE SAFETY CASE FOR THE MORSLEBEN REPOSITORY BASED ON PROBABILISTIC MODELLING

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The Morsleben nuclear waste repository (ERAM) for low- and intermediate-level mainly short-lived waste is located in a former salt mine. The closure concept was developed in parallel and interacting with the safety assessment. The safety concept is based on extensive backfilling with salt concrete complemented with seals between the main disposal areas and the rest of the mine building. Thus, the entire system exhibits a barrier effect through a partially redundant combination of several processes. However, in the formal safety assessment no credit is taken from the barrier effect of the extensive backfill.

In the safety assessments, the different possibilities of system development, the resulting array of potential fluid movement and a large number of potential radionuclide migration pathways are mapped in the bandwidth of derived parameters. The calculated response of the system to parameter variations is non-linear. Different processes may compete and compensate each other. Hence, the common practice to choose a “conservative” parameter set for the safety assessment is a priori impossible.

The safety assessment has been performed independently by two groups with different computer models, for the same closure concept and the same basic parameters but independent conceptual approaches. Both groups have performed deterministic and probabilistic dose calculations. The results match well; the differences can be explained on basis of the model approaches. Although a large

bandwidth is considered for a number of parameters, the maximum radiation exposure remains clearly below the applicable dose limit for nearly all calculations, demonstrating the robustness of the system. These aspects significantly contribute to confidence building in the Safety Case for ERAM.

# EUROPEAN PILOT STUDY ON THE REGULATORY REVIEW OF THE SAFETY CASE FOR GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

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**P. Bodenez**
Nuclear Safety Authority (ASN), France

***Et al.***

A number of countries within Europe are developing or giving consideration to the development of geological disposal facilities for the disposal of high level radioactive waste. The safety authorities in these countries are interested in exploring the possibility of a harmonised approach to the demonstration of safety of such facilities and the regulatory review of documentation providing such demonstration. As such, and with technical support organisations and international bodies, they have initiated a pilot study on how these elements should be presented in a safety case, for, *inter alia*, regulatory review and approval. It is envisaged that such a study will cover assessment of the site and engineering, impact assessment and assessment of the management systems ensuring quality and will be compatible with internationally agreed safety standards, guidance and recommendations. It is foreseen that the safety case will evolve and mature as the project develops and this aspect has been considered within the pilot study, together with regulatory review and decision-making at discrete milestones associated with the disposal facility development. The study is focussed on regulatory expectations for the different milestones and addresses uncertainty management. The paper present the work carried out to date and the views for future work.

# FROM INITIAL SAFETY CONSIDERATIONS TO A FINAL SAFETY CASE: FORMS AND PURPOSES OF SAFETY ANALYSIS DURING A DISPOSAL PROJECT'S LIFETIME

**J. Vigfusson**
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During preparation and realization of a radioactive waste disposal project a multitude of decisions are taken which require input from an assessment of the radiological safety of the disposal facility. Depending on the stage of the project and the purpose of the assessment, the safety assessments that are needed - or are possible - vary in comprehensiveness and in the choice of safety indicators. The paper compares the suite of safety considerations employed from the beginning of the search for a suitable radioactive waste repository site until the final closure of the repository. The reference material mostly derives from the regulatory basis and actual planning of the Swiss repository projects but illustrative examples are also taken from other national programs.

# DATA GATHERING AND LONG-TERM MAINTENANCE OF CONFIDENCE

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Public Agency for Radioactive Waste Management (PURAM), Hungary

According to the Hungarian legislation safety assessment is required in the preparation, establishment, operational, closure-licensing phase of repository development and during the operation of the repository the safety assessment should be reviewed regularly. It means that the safety assessment will be made many times during the repository development process; between two consecutive safety assessments more decades may elapse and between the first and the “last” safety assessment more than one century will elapse. The assessment of long-term safety is based partly upon geoscientific information. How can we maintain the confidence in the existing geoscientific information for many decades? What kind of metadata do we need to integrate into the multi-disciplinary geoscientific databases additionally for that purpose? The presentation sets forth the Hungarian practice and the existing difficulties recognized up to now.

# FOCUS ON ISOLATION AND CONFINEMENT RATHER THAN ON POTENTIAL HAZARD: AN APPROACH TO REGULATORY COMPLIANCE FOR THE POST-CLOSURE PHASE

**B. Baltes, A. Becker, A. Kindt and K-J. Röhlig**
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In recent years, consequence calculations have been put in perspective in relation to other evidence used in a Safety Case. The authors believe that this development is a good and necessary one but that such calculations still have an important role to play in a Safety Case. There is, however, no single and recognised way in which to judge the regulatory compliance of calculation results in the regulatory process. The approach for the presently ongoing revision of Safety Criteria in Germany is based on demonstration of the confinement of radionuclides. Calculated radionuclide concentrations in the accessible environment are seen as primary safety indicators which allow, together with other lines of evidence, to judge about the confinement capability of a repository system. Dose is not seen as indication of hazard to a hypothetical individual but as a means to judge about calculated concentrations.

# SAFETY REQUIREMENTS FOR THE DEEP GEOLOGICAL DISPOSAL IN UKRAINE

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The paper provides information about the current state of regulation development for deep geological disposal in Ukraine.

The regulation entitled “General Provisions on Safe Disposal of Radioactive Waste in Geological Repositories” (henceforth – the regulation) has been developed in compliance with the Comprehensive Programme of Radioactive Waste Management. The regulation establishes basic criteria, requirements and conditions for nuclear and radiation safety to be ensured in the disposal of radioactive waste that is subject to disposal in stable geological formations, compliance with Ukrainian legislations, at all life stages of repositories with the purpose of protecting personnel, the public and the environment.

The Law of Ukraine “On Decision Making Procedure for Siting, Design, Construction of Nuclear Facilities and Radioactive Waste Management Objects of National Value” establishes legislative and organisational provisions for siting, of nuclear facilities and radioactive waste management objects and determines procedure for decision making for repositories designed for disposal of spent nuclear fuel or radioactive waste.

# THE ENVIRONMENT AGENCY'S ASSESSMENT OF BNGSL'S 2002 POST-CLOSURE SAFETY CASE FOR THE LOW-LEVEL RADIOACTIVE WASTE REPOSITORY AT DRIGG

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Environment Agency of England & Wales

The Environment Agency of England and Wales regulates radioactive waste disposal in accordance with the Radioactive Substances Act 1993 (RSA93). British Nuclear Group Sellafield Ltd (BNGSL) is currently authorised to dispose of solid low-level radioactive waste (LLW) at a repository near the village of Drigg, close to the Cumbrian coast in North West England.

In accordance with Government Policy, we review authorisations for the disposal of radioactive waste periodically. We assessed BNGSL's 2002 Post-Closure Safety Case (PCSC) for the LLW Repository (LLWR) to inform our recent review of the Drigg Authorisation.

The 2002 PCSC considers the long-term impacts of the facility on the environment and the public, after waste emplacement operations have ceased, and includes a Post-Closure Radiological Safety Assessment (PCRSA).

The paper presents an overview of our assessment of the 2002 PCSC for the LLWR at Drigg, with particular emphasis on developing and implementing procedural aspects, rather than on the specific review findings and recommendations. Whilst our review was specifically focussed on an existing disposal facility for low-level radioactive waste, we consider it has highlighted some important issues that might be considered when developing and implementing a process to review a safety case for a new, deep geological disposal facility.

# PERSPECTIVES ON DEVELOPING INDEPENDENT PERFORMANCE ASSESSMENT CAPABILITY TO SUPPORT REGULATORY REVIEWS OF THE SAFETY CASE

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The U.S. Nuclear Regulatory Commission (NRC) has the responsibility under U.S. statutes and regulations to conduct a review of the U.S. Department of Energy (DOE) license application for a potential high-level nuclear waste repository at Yucca Mountain, Nevada, USA. A key component of the DOE license application will be a total system performance assessment to demonstrate compliance with regulatory requirements for postclosure repository performance. The NRC staff, with assistance from the Center for Nuclear Waste Regulatory Analyses (CNWRA), has developed an independent performance assessment review capability that includes applying available risk insights to be able to identify those aspects of the DOE post-closure safety case that are most important to demonstrating regulatory compliance. To advance the development of risk insights, the NRC and CNWRA staffs have developed an independent total system performance assessment model of the potential Yucca Mountain repository. This paper provides an overview of perspectives gained from the development and iterative improvement of independent total system performance assessment capabilities and how those capabilities will aid in the regulatory review of the DOE performance assessment.

# Session IV

## THE EMBEDDING OF THE SAFETY CASE IN SOCIETAL DIALOGUE AND DECISION MAKING

# SOCIETAL DIALOGUE AND DECISION MAKING ON SAFETY: CANADA NWMO'S EXPERIENCE

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According to the 1998 Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel (the Seaborn Panel), past work in Canada on long term used fuel management approaches had given insufficient consideration to the social dimension of safety and the social acceptability of the concept being developed. Following upon the findings of the Seaborn Panel, understanding and addressing the social dimension of safety was at the heart of the three year study conducted by the Nuclear Waste Management Organization (NWMO) and is at the heart of the recommendation which emerged from that study for Adaptive Phased Management.

NWMO's work is based on an understanding that judgments about risk and safety must be made collaboratively with citizens. From a social perspective, safety and acceptability are intertwined. Society as a whole, and not science alone, needs to judge the benefit or harm. While science can speak to the probability of the occurrence of an event, science cannot speak to social tolerance for its occurrence. What poses risk, how the risk should be measured, and what is considered relevant for measurement are all decisions which are influenced by societal considerations. That is why the NWMO designed its study of approaches so that a preferred approach would be developed through an iterative and collaborative dialogue involving both specialists and citizens. The preferred approach, Adaptive Phased Management (APM), itself attempts to enshrine this collaborative process as a key element of the approach. In particular, APM is designed to facilitate the iterative and collaborative development of the safety case through the process of implementation.

This paper will touch upon what citizens said about: the objectives, values and ethical principles against which the performance of the management system

ought to be assessed. It will outline the public requirement for the involvement of multiple and diverse interests in decision-making, and particularly those most potentially affected, to direct the pace and manner of implementation. It will also outline what citizens said about research and development work which will need to be conducted as part of the implementation, as well as the need for continuous learning, adaptive staging, and iteration as requirements of any social licence to proceed.

# THE PARTNERSHIP EXPERIENCE ON THE DISPOSAL OF LOW- AND INTERMEDIATE LEVEL SHORT-LIVED WASTE IN BELGIUM

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Study and Consultation Radioactive Waste Dessel, a non-profit organisation (STORA Dessel), Belgium

On June, 23 2006 the Belgian Government decided that low- and intermediate-level short-lived waste (category A waste) will be disposed of in a near-surface repository on the territory of the Dessel municipality. This decision implies that ONDRAF/NIRAS, in further interaction with the local stakeholders, can start the preparation of a licence application.

The governmental decision was the endpoint of the pre-project phase (1998 - 2006), during which local stakeholders from four municipalities were involved in local partnerships with ONDRAF/NIRAS. The decision was made on the basis of the final reports of the partnerships of Dessel (STOLA, now STORA) and Mol (MONA), approved by their municipality councils, and on ONDRAF/NIRAS' final report, confirming the feasibility of the proposed disposal systems.

The positive local decision in Dessel, both on the level of the partnership STOLA as on the level of the municipality council, to accept a disposal facility on their territory was the result of a 6 years long process of discussions within the partnership of all aspects of the disposal system and its integration in the municipality. During these discussions, both near-surface and deep disposal have been considered as relevant options. The local stakeholders in Dessel expressed in their final partnership report no preference for one of the two options.

The confidence by the local stakeholders in the safety of the disposal system resulted from an open, structured discussion of all safety related arguments. This paper will describe and discuss:

- the approach that was taken to organise and structure the information exchange and discussions between ONDRAF/NIRAS and the local stakeholders on all the safety related aspects of the case for deep disposal in Dessel;
- the major factors determining and affecting the confidence by the local stakeholders of Dessel in the safety of the system;
- how the concept of a safety case was used and applied to obtain the decision, both on the local and national level, to bring the disposal programme to a project phase.

Both the views of and lessons learnt by the local stakeholders of Dessel and ONDRAF/NIRAS will be presented.

# NYE COUNTY NEVADA LOCAL PERSPECTIVE OF THE YUCCA MOUNTAIN PROJECT (YMP)

**D. Swanson**
Nye County Nuclear Waste Repository Project Office, USA

Nye County, Nevada, is host of the proposed Yucca Mountain nuclear waste repository. The Department of Energy's (DOE) Nevada Test Site (NTS) and the Department of Defense's Nevada Test and Training Range occupy a large portion of Nye County. The NTS has been the site of numerous nuclear device detonations; hosts two low-level nuclear waste landfills; and was (and is) the site of various nuclear physics experiments and tests that have resulted in the distribution of radionuclides into the environment.

The Nuclear Waste Policy Act Amendments of 1987 designated Yucca Mountain as the only site, of the three sites approved for characterization, to be evaluated as a repository. The Act includes provisions for local involvement in program oversight. Nye County and each county surrounding Nye is designated an "affected unit of local government" (AULG). Nye, being the situs county, also is provided the opportunity to have an "on-site representative". This function is a day-to-day opportunity to interact with DOE staff and be actively involved in the DOE decision-making process.

DOE has recognized Nye County's unique status and special needs and has provided additional funding for various studies via cooperative agreements. The most notable program is the County's Independent Science Investigation Program (ISIP). This unique program allows Nye County to contract with subject matter experts, primarily hydrological and geotechnical experts, to conduct studies and advise the county regarding their results and the technical results of DOE's investigations. Through the ISIP, Nye has developed a cooperative and credible relationship with numerous research facilities including the national laboratories, government agencies, and universities.

Nye County has no viable means to reject the YMP. Hence, current County policy is of a pragmatic nature in that our objectives are to assure that public

health, safety and the environment are adequately protected, that the YMP is a success in every way possible, and that Nye County benefits economically from the project.

# THE EMBEDDING OF THE SAFETY CASE IN SOCIETAL DIALOGUE AND DECISION MAKING

**K. Nilsson**
Local Competence Building in Oskarshamn (LKO) - Municipality of Oskarshamn, Sweden

Oskarshamn is one of two Swedish municipalities where site investigations are conducted by SKB as possible sites for a final repository for spent nuclear fuel. The municipality has been an active part in the process since 1994 when Oskarshamn was pointed out as a suitable site for an encapsulation plant. A project organisation LKO – Local Competence Building was set up 1994 and it is financed by the Swedish nuclear fund.

There are two leading themes that form the basis for our participation – complete openness of plans and results and participation with the possibility to influence.

Site investigations for a repository started 2002 and will be finished when SKB has selected a site, which is planned late 2009. To follow up the site investigations, an organisation based on working groups has been set up. The groups are the Safety Group, The Misterhult Group and the Future Perspective Group. About 45 persons are participating in the groups. The members are politicians, civil servants, people representing various associations and interested citizens.

The main goal for the LKO organisation is to present a comprehensive report to the municipality council if SKB will apply for a final repository in Oskarshamn.

When the municipality council accepted site investigations the decision was taken with 13 conditions. The most important conditions are about long term safety.

# Poster Session

# TO WHAT EXTENT CAN NATURAL ANALOGUES CONTRIBUTE TO THE SAFETY CASE OF HIGH LEVEL WASTE REPOSITORIES

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The most important key element of any safety case for a planned radioactive waste repository is the safety assessment. It quantifies potential hazards to the environment from selected scenarios by means of numerical model calculations. A time frame for the assessment of 1 million years is proposed in the course of the revision of the German safety criteria. Due to the growing uncertainties in the safety assessment within the extended/geological time frame, additional arguments supporting the modelling results as well as the conclusions to be drawn will be of increasing importance.

One category of supporting arguments can be derived from natural analogues. Their role in the safety case depends to some extent from the time period which they cover. Especially industrial or archaeological analogues can help understanding and underpinning of short-term processes. However, the main benefit of natural analogues in a safety case is to increase the understanding of long-term processes.

In this paper it is evaluated in what way natural analogues can contribute to the different elements of a safety case. This is illustrated by discussion of their use for different time frames exemplary for a potential repository in rock salt.

# GEOLOGICAL REPOSITORY PROGRAMME IN THE CZECH REPUBLIC - CURRENT STATE OF THE SAFETY CASE

**S. Konopaskova**
Radioactive Waste Repository Authority (RAWRA), Czech Republic

The Czech deep geological repository programme has been recently divided in four principal subtasks: siting, near field and far field studies and safety issues. In the forthcoming period, the first three of these projects will support the construction of a safety case.

Until today, the safety case is constructed for an actualized version of reference project that provides more options of design and engineered barrier system including materials used for containers construction, backfill and sealing. Basic sensitivity studies of near field and far field are available and comparative biosphere calculations are in progress. The modelling approach and data application have been verified by comparative studies. Near field studies concentrate on choice of materials that could be applied for the repository construction. Ongoing research provides the information on data usable in safety calculation, mostly obtained from migration experiments, corrosion rate studies and material thermal stability evaluation. Inventory calculations and thermal loading of spent fuel are continuously actualized with respect to the up-to-date knowledge concerning power plants operation and future decommissioning data. Confidence building is presently built using natural and anthropogenic analogue studies.

Participation in international programmes should raise the credibility of adopted decisions that are continuously carried out in the safety case construction process. Czech institutions that are involved in the safety case and environmental impact assessment activities take part in many IAEA, NEA OECD, EC and other international projects.

# APPLICATION OF ARCHAEOLOGICAL ANALOGUES FOR REPOSITORY SAFETY CASE: ARGUMENTS SUPPORTING THE WASTE CONTAINER LIFETIME

**H. Yoshikawa, K. Ueno and M. Yui**
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In the H12 safety case for a generic Japanese HLW repository, a carbon steel container (overpack) was designed with a 1 000 year lifetime, based on a corrosion allowance of 40 mm derived from laboratory data obtained under anaerobic conditions. Analogue studies have been conducted to increase confidence in the robustness of this design basis, in parallel with corrosion experiments for extended periods (a few years or more). Using X-ray computer tomography (X-CT), about 40 samples of iron archaeological artifacts, which were found at Japanese ancient monuments after burial underground for a few hundred to one thousand years, were analyzed. The thickness of the corrosion layer was measured nondestructively by X-CT and main components of the rust were analyzed by X-RD or destructive chemical analysis for some samples. The measured corrosion rates are more than one order of magnitude less than the design allowance of 40 mm/ka, which supports the argument that the designed corrosion allowance is conservative. In particular, some samples excavated from clay layers in an ancient tomb can be considered to be under reducing conditions and were corroded at most 2 mm in 1 000 years. Such archaeological study can provide useful evidence for long-term lifetime of a waste container, which is an important element for making a robust safety case.

# APPLICATION OF A TIMEFRAMES APPROACH TO PERFORMANCE ASSESSMENT

**M.J. Poole**
United Kingdom Nirex Limited

In past Nirex performance assessments, there has been no explicit representation of the time-dependent evolution of the repository system and sub-systems. Nirex has recently proposed a development to the presentation of the performance assessment, in which the assessment period is divided into a number of timeframes.

This poster will explain how the timeframes will be defined on the basis of the safety functions of the main barriers to radionuclide release. The timeframes will correspond to a period of absolute containment, the barrier provided by the waste package, the chemical barrier and the geological barrier. Consideration will also be given to demonstrating continuing safety in the far distant future. The poster will explain how each timeframe is associated with a particular spatial scale.

Rather than considering the timeframes as occurring one after the other, they are best regarded as “nested”. This is because the safety functions of the different barriers operate together, rather than sequentially – for example, the geological barrier is present all the time, the chemical barrier will be operating whilst packages are still intact. The relevant timescales for the timeframes are deliberately open-ended. This reflects both the uncertainty associated with the timing of the key stages in the repository system evolution, and the variability associated with the duration of the safety functions.

The poster will describe how the results of performance assessment modelling using the GoldSim software, which will include a representation of time-dependencies of key processes, will be used to present the arguments for safety in each timeframe.

# SAFETY CASE FOR DISPOSAL FACILITIES-CONFIDENCE BUILDING AND REGULATORY REVIEW: IAEA ASAM COORDINATED RESEARCH PROJECT

**M. Ben Belfadhel**
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International Atomic Energy Agency (IAEA)

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**W. Goldammer**
Consultant, Germany

The IAEA successfully concluded a Coordinated Research Program (CRP) called ISAM, which focussed on the development of an Improved Safety Assessment Methodology for near-surface radioactive waste disposal facilities (1997-2002). In November 2002, and as an extension of ISAM, the IAEA launched a new CRP called ASAM, designed to test the Application of the Safety Assessment Methodology by considering a range of near-surface disposal facilities. The ASAM work programme is being implemented by three application working groups and two cross-cutting working groups. The application working groups are testing the applicability of the ISAM methodology by assessing an existing disposal facility in Hungary, a copper mine in South Africa, and a hypothetical facility containing heterogenous wastes, such as disused sealed sources. The first cross-cutting working group is addressing a number of technical issues that are common to all near-surface disposal facilities, while the second group, the Regulatory Review Working Group (RRWG) is developing guidance on how to gain confidence in safety assessments and safety cases, and on how to conduct regulatory reviews of

safety assessments. This paper provides an overview of the ASAM project focussing on the safety case and its regulatory review.

# C-14 IN THE SAFETY CASE

**G. Bracke and W. Müller**
Institute for Safety Technology (ISTec), Germany

C-14 is a versatile nuclide, which has to be evaluated in the safety case in detail due to its half life of 5340 years and impact to the biosphere. Assessing the potential radiation exposure by C-14 requires modelling of the liquid phase as well as of the gaseous phase and their interaction due to geochemical reactions.

A simplified modelling of potential radiation exposure by C-14 of a final repository in salt rock results in an overestimation of the dose. In our assessment of this modelling we suggest therefore the use of realistic assumptions for release of C-14 activity to the liquid phase as well to the gaseous phase in order not to overestimate the potential radiation exposure.

The technical details of these suggestions will be presented for understanding and its proposed implementation in the safety case.

# PRE-CLOSURE SAFETY ANALYSIS FOR SEISMICALLY INITIATED EVENT SEQUENCES

**M.J. Shah**
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This paper describes a methodology to determine probabilities of occurrence of seismically initiated event sequences, considering event occurrence probabilities and performance of structures, systems, and components (SSCs). The methodology can be used to assess safety of the pre-closure facility for the seismic hazard at the proposed geologic repository at Yucca Mountain, Nevada, and to demonstrate compliance with the risk-informed, performance-based regulations in the U.S. Code of Federal Regulations, Title 10, Part 63. The probability of occurrence of an event sequence leading to an SSC failure is determined by convolution of the seismic hazard curve with the conditional failure probabilities (i.e. fragility) of the SSCs. The methodology is illustrated using examples of potential event sequences. The methodology described in the paper shows how the safety of a facility during a seismic event can be determined using the performance-based regulations. The scope of the paper is limited to estimating the probabilities of occurrence of potential event sequences leading to failure of SSCs and potential release of radioactivity; it does not discuss dose or risk estimates.

# SAFETY ASSESSMENTS OF ULTIMATE ISOLATION OF RADIOACTIVE WASTE IN DEEP GEOLOGICAL FORMATIONS IN RUSSIA: OBJECTIVES, PROBLEMS, PROSPECTS

**T.A. Gupalo, V.S. Gupalo, V.Yu. Konovalov**
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Main objectives of safety assessments of the ultimate isolation of radioactive waste (RW) from the human environment in deep geological formations are:

- justification of efficiency of technical solutions used for the ultimate isolation and assessment of critical man-induced impact of the facility on the environment and population;
- analysis of how safety indicators depend on the facility and host rock parameters to determine key protective functions and their parameters and to identify main critical events and phenomena producing a significant impact on the facility safety.

To solve these tasks, the deterministic methodologies and computer codes have been developed and widely acknowledged in Russia, which allow for calculating these parameter values with the known dynamics of changes of the facility parameters, its hosting environment and impacts of factors of different nature.

This approach, however, does not allow for adequate safety projections of ultimate isolation for longer term. Therefore, methods and computer codes for probabilistic safety assessments and analyses have started to develop in Russia.

Main problems that hinder the safety analyses and justifications, which are faced by researchers worldwide, are obtaining input data which describe processes of radionuclide contamination migration in the geological environment (migration characteristics) and projecting the dynamics of changes in parameter values of the host rock.

To determine migration parameter values, field studies are carried out in Russia on the behavior of radionuclide contamination having a complex composition in rock mass; their results can be used by international researchers as input data for the probabilistic safety analysis.

The expertise accumulated in Russia in operation of underground facilities, which have been producing heat impacts to the host rock for decades that are similar to impacts to be produced by the RW ultimate isolation facility, can be used to solve the issue of projecting parameter changes of the geological environment hosting the RW repository.

# DEVELOPMENT OF THE SAFETY CASE OF GEOLOGIC REPOSITORY IN KOREA

**C-H. Kang, Y-M. Lee and Y-S. Hwang**
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A national energy security in Korea is dependent on the peaceful and safe utilization of nuclear energy. The nuclear option is the only practical solution to accomplish this mission in Korea. The Korean Government's policy on nuclear energy can be summarized into two principles: promotion of the peaceful uses of nuclear energy and securing its safety. Since April 1978, Korea has strongly relied on nuclear energy for its electricity generation. As of today, nineteen nuclear power plants, 15 PWRs and 4 CANDUs, are in operation and nine are to be inaugurated by 2015. The installed nuclear capacity is 16.7 GWe, representing 29% of the nation's total installed capacity. The nuclear share in electricity remains at around 40.2 reaching a level of 130 billion kWh's. New power reactors, Korea Standard Nuclear Power Plants are fully designed by domestic technologies. More advanced reactor named AP1400 will be commissioned in 2010.

The Korea Atomic Energy Research Institute (KAERI) launched a three-step 10-year R&D program in 1997 to develop a reference geologic repository system for HLW by 2006. A preliminary reference repository concept for spent PWR and CANDU fuel was proposed. A site for the underground repository has not been specified, but a generic site with granite rock was suggested for this study. The waste packages will be vertically placed in boreholes drilled in the floor of the deposition tunnels or horizontally placed in the deposition tunnels located about 500m below the surface in a crystalline rock mass. In parallel, the overall system performance assessment code for a probabilistic safety assessment has been developed. To accomplish a TSPA, a systematic development of the FEP list was pursued. Based on the KAERI FEP Encyclopedia, reference and alternative scenarios were developed. By applying the TSPA code, a preliminary safety assessment was performed by using the generic data set. Results showed that the current disposal concept proposed by

KAERI satisfies the safety criteria for the given radionuclide release scenario. In the future, detailed TSPA will be performed by using the Korean geologic data and a more detailed disposal concept.

# NOTES

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