Radioactive Waste Management
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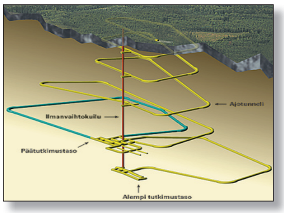
Regulating the Long-term Safety of Geological Disposal of Radioactive Waste: Practical Issues and Challenges

Workshop Proceedings
Paris, France
28-30 November 2006



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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

The NEA Radioactive Waste Management Committee (RWMC) Regulators' Forum (RF) strives to improve understanding of the similarities and differences in waste management regulatory programmes around the world to ensure that experience can be shared and that the legal, cultural and societal factors influencing this experience have been ascertained. As part of its endeavours, the Regulators' Forum established the Long-term Safety Criteria (LTSC) initiative in 2004 to investigate the criteria used in member countries to regulate the disposal of long-lived, high-level radioactive waste. The LTSC organised an international workshop in November 2006 to explore different perspectives on long-term safety regulation, from the starting point that:

(1) this process involves not only technical considerations, but necessarily reflects societal values on issues such as the appropriate balance between risks from hazardous activity given the associated benefits; and

(2) differences in criteria across countries are likely to result largely from such non-technical considerations.

The workshop was attended by 43 participants from various backgrounds (philosophy, theology, sociology and political science in addition to the relevant technical fields) representing regulators, implementers, consultancies, research centres, academic institutions, the NEA and the European Commission (EC). RWMC working groups, such as the Integration Group for the Safety Case of Radioactive Waste Repositories (IGSC) and the Forum on Stakeholder Confidence (FSC), were well represented at the workshop.

The viewpoints expressed during the workshop have been summarised herein and address the necessity for diversity of regulatory processes; the basis and tools for assuring long-term protection; ethical responsibilities of one generation to later generations and how these can be discharged; and adapting regulatory processes to the long time frames involved in implementing geological disposal. The summary of viewpoints presented in these proceedings have been reviewed and commented upon by the workshop participants.

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1. SYNTHESIS OF EXPRESSED VIEWPOINTS

Introduction

A variety of viewpoints were voiced at the workshop either in oral presentations or in the ensuing discussions. These viewpoints have been collected and organised in six broad areas. Workshop participants have contributed by reviewing and commenting on the present collection of viewpoints, which is provided for convenience. More detailed and precise information is provided in the summary of the workshop and the contributed papers.

The workshop programme is shown in Appendix 1 to this report.

Necessary diversity of regulatory processes and regulation

- There appear to be wide variations in numerical criteria. However, these should be looked at in the broader frame of:
  - assessment approaches (e.g. "conservative/bounding" vs. "realistic", and how to address sources of uncertainty);
  - the basis for criteria (absolute risk; dose based on current radiation protection criteria; or dose based on comparisons to natural levels);
  - compliance judgements (limit vs. target, "hard" vs. "soft", …); and
  - on whether and how the criteria should change with timescale.

- For the above reasons, simple direct comparison of long-term numerical criteria used in different member countries may provide a misleading picture unless the broader context of how the criteria are implemented is taken into account. Other reasons amplified in the discussion paper include the complexity and non-uniformity of the regulatory decision-making process across nations; different approaches on how to characterise and define protection in the distant future; different approaches to dealing with ethical issues related to the nature of current society obligations to the future; and, reflecting all of this, international guidance that has been evolving in time and still is in the process of evolution (e.g. the recent ICRP guidance development process).

- Regulatory policies and decision making are not solely based on technical matters. They take into account expectations of civil society, international experience, ethical considerations and the practical needs of implementation. Accordingly, it is important to consider "the regulatory system" or the societal decision-making process, rather than simply "the regulator". The decision making process involves a range of national institutions encompassing government, parliament and other players besides the lead technical regulatory authority that is responsible for the licensing and approval process.

- Since it must be assumed that, eventually, institutional control of a disposal facility will no longer be maintained, licensing of geological disposal may be seen an act of trust not only in the regulator, but in the broader regulatory system and decision-making process.

- In general, the workshop participants agreed with new ICRP recommendations (draft 2006), which recognise that decision-making processes may depend on a variety of societal concerns and considers that the involvement of all concerned parties is needed to achieve more flexible and sustainable decisions.

Assuring long-term radiological protection

- There was common ground amongst all participants on the importance of providing a high level of protection. On the other hand, the lack of capacity for perpetual active protection should be acknowledged in regulations.

- The public and those affected by implementation of a repository are more likely to accept repository proposals if their cultural, societal and ethical views have been considered alongside the technical considerations in formulating a strategy for testing repository performance. The regulator may want to interact with the public on this specific aspect and receive feedback.

- In Cordoba (1997) there was consensus that numerical criteria for radioactive waste disposal should be considered as references or indicators, addressing the ultimate safety objectives, rather than limits in a legal context. A number of important aspects were emphasised such as the nature of long term performance assessments, which are not predictions but rather illustrations of long-term behaviour and safety. The notion of potential exposure[1] was emphasised.

- The evolution of the international guidelines over time (see ICRP-81) indicates that dose and risk may lose their significance as measures of health detriment beyond a few hundred years, however calculated dose and risk over the long term can be utilised as indicators of protection provided by the disposal system. Virtually any other indicator may be subject to uncertainty over the long term, which has lead to increasing attention being placed on sound engineering practices, and the progressive introduction of additional concepts that reflect the level of confidence that the disposal system can discharge its defined safety functions (e.g. constrained optimisation, BAT, and application of sound managerial principles to repository design and implementation).

- There appears to be today an *increasing* use by implementers of the concept of safety functions, whereby one or several system components can contribute to a single safety function or, vice versa, where a single component may contribute to several safety functions.[2] Implementers use the concept of safety functions in order to design, describe and help evaluate the performance of the disposal system.

- The Cordoba Workshop (1997) observed that there may be no widely accepted basis for the use of timescale cut-offs, although they may provide a pragmatic basis for regulatory decisions. Accordingly, some nations may choose to focus on a time frame which avoids consideration of a new ice age when all aspects of life may be so impacted that the repository may be minor in comparison; other nations may decide that impacts to the first several generations are more important than those occurring after millions of years. The different

1. Dose and risk – as used in the context of long-term management of waste – are potential doses and risks in the sense of ICRP-81. According to the latter: "The term "potential exposures" refers to situations where there is a potential for exposure but no certainty that it will occur, i.e. the type of situations of concern in the long term following closure of a solid radioactive waste disposal facility" [see par. 24].
2. See, for instance, Sect. 3.1.3 of the "Time frames" document of the IGSC http://www.nea.fr/html/rwm/docs/2006/rwm-igsc2006-3.pdf.

approaches respond to different national contexts. It was observed, that where cut-offs are used, their basis and use ought to be explained.[3]

- As shown by the time frames study of the IGSC, the direct radiation hazard from some high level radioactive wastes remains at significant levels for very long periods, beyond hundreds of thousands of years and beyond conventional periods of regulatory concern.[4] Isolation (removal of waste from the accessible environment) thus adds value for much longer times than indicated solely by dose calculations based on ingestion (radiotoxicity) considerations.

- It would be helpful, for decision-making purposes, if the safety case provided comparison with other management options and an indication of the fate of the repository in the very long term.

- In formulating a radiation protection strategy and test for long term performance of the repository, societal, cultural and ethical views along with technical perspectives may be important in the selection of national performance criteria and time frames. International efforts should be directed at promoting exchanges among nations to understand the bases for safety objectives and performance strategies to identify similarities and differences.

Tools to demonstrate repository performance

- The workshop expressed a common view that assuring a high level of radiation protection requires tools to demonstrate acceptable performance of the repository system. To enhance public confidence, many countries are examining a range of complementary indicators to dose and risk, including multiple lines of reasoning. Where complementary indicators are used, it is important to consider the practicality of implementing such indicators in terms of demonstrating compliance with regulatory standards. Also, such indicators should focus on repository system functions most important to repository performance.

- There appears to be an increasing attention to approaches supporting constrained optimisation, use of best available techniques (BAT), use of multiple lines of argument, including and use of supplementary indicators to dose and risk. The concepts of as low as reasonably practicable (ALARP) or best available techniques (BAT) would require, however, additional clarification and international reflection. Some reflections are as follows:
  - Optimisation is constrained by a variety of factors, including societal, economic and technological constraints. Optimisation may thus be applied not only to calculated outcomes of performance analyses, but also to other aspects.
  - Optimisation requires a balance between short- and long-term protection. For instance, keeping a repository open for reasons other than safety needs to be balanced with the risk of increased accidents for mining personnel.
  - Some programmes make a distinction between optimisation and BAT. The former is concerned with reducing (radiological) impacts to ALARP based, e.g. on a dose target; the latter is about choosing techniques that minimise, to the greatest reasonable extent, the potential for releases though the barrier systems to occur (system robustness, sound siting and well-proven engineering practices).

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3. (a) There was a plea that regulation not go beyond times that can be reasonably predicted; (b) Cut-offs based on ingestion radiotoxicity are undermined by the fact that external exposure due to gamma radiation from SF (and HLW) continues at high level for several millions of years (see also next bullet point).
4. The IGSC study, NEA/RWM/IGSC(2006)3, shows that a relatively small piece of HLW glass or SF – if unshielded – is able to give doses in the order of millisieverts per hour over periods of millions of years.

– Given that it is not certain that impacts will occur ("potential exposures"), BAT may be regarded as the ultimate guarantee for safety. It is important to recognise that the BAT concept embodies not only technological aspects but also the managed process of implementation, e.g. sound siting and engineering practices; and to recognise as well that it embodies the element of practicability (see the definition of BAT in the IPPC Directive[5] of the EC).

– Accepting the priority of BAT vis-à-vis optimisation is a way of saying that safety is an intrinsic property of the system as designed and built. If safety is an intrinsic property of the system as designed and built, it can only be illustrated by means of some indicator (test or measures) related to the system features and functions, i.e. ultimately, indicators related to BAT. This had led to proposals for developing complementary indicators such as radionuclide fluxes through components of the system and radionuclide concentrations in the groundwater.

– The reliance that can be placed on calculated doses and risks decreases with time,[6] leading to an increasing need to consider also other indicators linked to the application of BAT.

- The circumstances in which generic reference values for safety indicators can be drawn from nature are not universally agreed.

- The safety case needs to explain the basis for the assumption that future scenarios are adequately bounded. It must be realised that, at times, hypothetical scenarios are created in order to perform calculations of exposures. For instance, we have come to accept *reference biospheres* and that safety assessments assume that future human beings will not change from those of the present day. Yet, human beings have existed for only about 200 000 years.[7]

- The workshop agreed that a range of technical tools is available for illustrating potential repository performance over the long term. Each of these tools has advantages and disadvantages for implementation and for use in a regulatory system. In selection of these tools for use by different countries, broad perspectives should be considered in determining their value for enhancing public confidence and well as serving as indicators in satisfying regulatory criteria.

Ethical concerns: burdens vs. responsibility and duties vs. capacity

- Ethical considerations are important when deriving regulatory requirements.

- Many waste management programmes have concentrated almost exclusively on technical aspects, or have used technical specialists to deal with ethical issues. This can and should be improved.

5. http://ec.europa.eu/environment/ippc/index.htm
6. It must be recalled that ICRP-81 suggests that dose and risk should not be seen as measures of health detriment beyond a few hundred years (from emplacement of the waste).
7. Indeed, could one not use this argument as one of the bases for cut-off in regulation? [Note that we do similar types of reasoning when we say that (a) no archives may be reasonably kept for more than 500 years, (b) monitoring and active surveillance can operate for a couple of hundred years only, (c) that our obligations are strongest during times that we can comprehend and are the typical times of our democratic institutions (200 years).]

- Most[8] ethicists accept that one generation has responsibilities towards succeeding generations, though views differ on the nature of these obligations and on their duration. There is the view that this responsibility extends so long as the impact persists, i.e. there is no cut-off. This absolutist view is countered by the more pragmatic position that responsibility necessarily must diminish in time reflecting capacity to discharge the responsibility. Even if it is argued, in the context of responsibility towards future generations, that the *duty of protection* does not change over time, it is clearly **accepted** that our *capacity* to fulfil the duty is time dependent.

- Timescales over which we must reflect about burdens and responsibilities to future generations might be sub-divided as follows:
  - the socio-cultural timescale (a few generations);
  - the timescale over which we have reasonable confidence in the safety assessment calculations;
  - the timescales for which materials performance and geological processes are reasonably predictable;
  - the timescales beyond which processes are beyond any reasonable quantitative prediction.[9]

- There is an increasing recognition that the timescale for implementation of any repository, even one that does not explicitly involve retrievability, nevertheless involves several generations, i.e. perhaps equivalent to the socio-cultural timescale mentioned above.

- Transferring burdens to succeeding generations cannot be avoided. Consistent with the sustainability principle, if burdens are transferred, then opportunities/rights should also be given.

- It would be useful to have tests for assessing that (a) duties that can reasonably be carried out are, in fact, performed; (b) remaining duties are transferred as responsibly as possible to subsequent generations in order to offer them maximum flexibility to discharge their duties; (c) transferred burdens (cost, risk, effort) are, at least partially, compensated by transfer of information, resources and continuity of education/skills/research.

Making the long-term disposal objectives clear and transparent

- The regulations have to be explained and understood by the public and it is crucial that regulatory criteria and requirements are formulated in such a way that "demonstration of compliance" is facilitated in a credible manner. It is also important to ensure some level of international consistency on fundamental safety and radiological protection objectives and issues. In this context:
  - One of the challenges for the regulator is not to promise, nor require, the impossible.
  - Concepts such as "safety", "reasonable assurance", "potential dose" and "potential risk", complementary safety indicators, etc. used nationally or internationally, ought to be defined clearly. Internationally agreed definitions would be especially beneficial for concepts where the relevant high-level objectives are common to all programmes. A case in point is the concept of "safety".

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8. There are some ethicists who hold that one generation does have responsibilities to later generations, but the rationale for this view is not widely accepted.
9. For such timescales there is no capacity for exercising responsibility.

  - Regulatory tests need to communicate clearly and honestly what is meant by "safety" (e.g. "no harm" is not the same as "no exposure"), promise no more than can reasonably be delivered by the disposal system, and provide for safety case information that supports and illuminates safety decisions appropriate for different time frames.
  - Sustainability is a concept that is not well defined in the context of disposal of long-lived radioactive waste. It would useful to reflect on the opportunities and difficulties that the concept may provide to the regulator and implementer. It is not clear that the sustainability language of the Joint Convention ("needs and aspirations of future generations") is implementable in the normative way that is expected of regulations.

- The precautionary principle applies to all the considered alternative waste management options, including the "do nothing" alternative and any undue delay in taking decisions.

- The public appears to have higher demands with respect to protection from hazards from radiotoxic wastes than from chemotoxic wastes.[10] It may be useful to investigate the reasons for this, in order to ensure that policy and objective-setting aspects of the regulatory process address it effectively.

Foreseeing and explaining the decision-making process

- In the context of the long duration of the project (perhaps more than 100 years) there will be technological progress and incremental development of the repository. Regulators and regulatory guidance will have to adapt to this reality. In this context:
  - There is an increasing attention to the connection between regulation and stepwise decision making. Relevant questions include: Should the formulation of regulations be understood as a stepwise process? If so, how can this process and the requirements it creates best be explained? How are judgmental issues going to be addressed? In the same vein, how should short- and long-term protection goals be balanced? What are the attributes of a robust process? How to guarantee a certain degree of stability regulatory positions, e.g. in order to allow a certain degree of legal and investment security for the implementers?
  - Dialogue between regulators and implementers is important in any licensing process. In the case of a stepwise decision-making process it is crucial that this dialogue start in the early phases of the process and continue all along the process. The dialogue ought to be managed so that the independence of the regulator is clearly maintained.

- The ability to intervene (control) is central to normal regulatory practice and to the concept of safety. Relinquishing control requires an act of trust – in the technology and the legal and regulatory systems – taken by the current generation on behalf of future generations. Decision-making process components ought to be designed to improve the perceived legitimacy of the process and therefore lead to improved trust.

- Factual and value-laden components of regulatory guidelines and licensing decisions need to be distinguishable, for the benefit of the public and for political decision makers. One

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10. According to the UK Sustainable Development Committee: "it is impossible to guarantee safety over long-term disposal of (nuclear) waste", which implies that nuclear fission power should be shut down; at the same time, in the same country, CoRWM, the Committee on Radioactive Waste Management, recommended geological disposal for existing wastes as a broadly acceptable solution.

difficulty faced by citizens is that the practical implementation of the regulations is an expert task and may not be transparent to members of the public. For this reason, some member countries recognise that host communities may wish to have access to expert advice on the technical issues under consideration.

- The general public is often concerned that decision making for implementation follows a legitimate process, i.e. one that is established in advance and is subject to democratic ratification. Key elements for success generally appear to include: openness and transparency, a staged process, participation, right to withdraw, partnership, and community benefits. This approach for decision making may also have implications for regulators, such as openness in decision making, greater consistency of regulation and integration of societal concerns.

- It may be argued that models of participation that have emerged during recent decades require further evolution in terms of providing for appropriate levels of public access to decision making.

2. SUMMARY OF PAPERS AND WRITTEN REPORTS

SESSION 1: SETTING THE SCENE

Carl-Magnus Larsson, Chair of the LTSC and former Chair of the Regulators' Forum, welcomed the participants. He recalled the background and objectives of the workshop. The RWMC Regulators' Forum (RWMC-RF) has worked on regulatory issues since 1999, and has started, through the LTSC (Long-Term Safety Criteria) initiative, to analyse differences in approaches to long-term safety, as depending on, and affected by, the regulatory environment. He stated that, since the work of the LTSC Group has been communicated to RWMC, it is now timely to make this work known and debated by a broader audience.

He outlined the workshop objectives which were to:

- Check where we stand in this field and confirm the findings so far.
- List open as well as closed issues.
- Identify agreed-upon results and challenges to take home.
- Identify a road map to future work.

He pointed out the tight agenda, which is supported by the discussion document previously distributed, and asked participants to concentrate on the major points rather than details. He acknowledged the work done by Carmen Ruíz-Lopez, David Bennett, Piet Zuidema, Richard Ferch, Allan Duncan and Claudio Pescatore.

Allan Duncan, expert to NEA and former Chief Inspector for Pollution (United Kingdom), elaborated on the regulatory function in the domain of radioactive waste management. The preparation of a document and a brochure on the subject has been one of the main tasks of the Regulators' Forum since its creation in 2001. He stressed that management of NORM waste was generally subject to different standards than similar radioactive waste from a nuclear source, for no obvious reason than that of public perception. He also pointed out the large number of "regulatory bodies" involved in the regulation of radioactive waste management facilities and particularly geological disposal facilities, and their links to the Government. He gave the example of the United Kingdom. He stressed the fact that, since there will not be continuous control, licensing of geological disposal is an act of trust in the regulatory system.

A. Duncan gave the position of two Commissions in England on deep geological disposal. The UK Sustainable Development Commission says, "it is impossible to guarantee safety over long-term disposal of (nuclear) waste" which implies that nuclear fission power should be shut down; CoRWM, the Committee on Radioactive Waste Management, recommends instead geological disposal for existing wastes as a broadly acceptable solution.

As a concluding remark A. Duncan focused the attention on the general question of what current society needs to do in order to meet its obligations to future generations with respect to disposal of long-lived wastes.

Carl-Magnus Larsson detailed then the work of the Regulators' Forum and the origin of the LTSC initiative. He explained that one of the objectives of the LTSC was to identify a set of issues on long-term protection criteria and collate findings in a report. He explained why the idea of a "collective opinion" was abandoned and why it should be replaced by a common understanding where differences between countries ought to be explained and understood.

C.-M. Larsson detailed the different types of approaches to regulating long-term safety and the different approaches for numerical targets. He gave some explanations of the reasons for the differences in regulatory targets between countries (level of conservatism, progress in the safety case methodology, etc.). The regulatory function takes into account the nature of the demonstration (illustrations and societal demands). C.-M. Larsson referred to the evolution of IAEA safety fundamentals and stressed that the "sustainability" concept, introduced by the Joint Convention, is not mentioned in the new safety standard. The term "adequately protected" is now preferred in relation to future generations. The ICRP recommends that less emphasis be placed on assessment of doses in the long term. C.-M. Larsson concluded that one of the challenges for the regulator is not to promise nor require the impossible.

Alan Hooper (UK Nirex) presented the issues on long-term regulation raised ten years ago at the Córdoba workshop. The main issue was the identification of "soft" approaches which, for the long term, should be preferred to "hard" approaches, since concentration on compliance with strict limits tends to obscure the concept. The consensus was that numerical criteria for radioactive waste disposal should be considered as references or indicators, addressing the ultimate safety objectives, rather than limits in a legal context. The notion of potential exposures was emphasised and it was recognised that risk, even though it has drawbacks, was in principle a more appropriate criterion than dose. A number of important aspects were emphasised such as the nature of long-term performance assessments, which are not predictions but rather illustrations of long-term behaviour and safety. Other subjects were considered such as the application of optimisation, the stepwise approach to setting up regulation, the possibility of progress towards convergence of regulations even though criteria are strongly national, the benefits of dialogue between implementers and regulators, the important role of multiple lines of reasoning, the need for regulatory guidance on protection of the environment, and the need to establish time frames for the application of numerical criteria and the basis for setting a time cut-off.

A. Hooper listed improvements to be made which were identified at that time, including treatment of uncertainty; the elicitation and use of expert judgment; the clarification on what is meant by concepts of confidence building and/or reasonable assurance; the need for transparent, auditable presentation of methods and results for the benefit of political decision makers and the public; the need to publish safety criteria well ahead of license application; and the need for the establishment of a stepwise approach for the process.

A. Hooper presented the main conclusion of the Córdoba workshop which was that a common basis exists in terms of the methods used and of the understanding of the main issues. Some issues are relatively generic such as the stylised approaches, management of uncertainties, and the risk concept; therefore they are amenable to resolution through international studies. Other issues are strongly influenced by national administrative, legal and cultural considerations, so national differences would be expected. A concluding comment was that international harmonisation makes sense at the level of the overall safety objectives, rather than in detailed regulatory criteria.

Peter de Preter (ONDRAF/NIRAS) presented the findings from the Timescales Initiative of the IGSC. He explained why considering the long term is important for safety assessment and what its challenges are. Some ethical questions were raised such as how far our responsibilities reach and what is the flexibility that should be given to future generations for their own decision making, and the implications of this for the phased planning of the repositories. He acknowledged that coming to a balanced and socially accepted view is still a matter of debate in many programmes and internationally.

P. de Preter explained that regulations specify what needs to be shown, and in some cases over what time frames. He presented the conclusion that the limits to the predictability of the repository and the environment need to be acknowledged in safety cases, and that calculated doses are only "potential doses" since actual dose and risk to future generations cannot be forecast with certainty. He recognised that stylised assumptions are used regarding the biosphere and human lifestyle or actions, and that conservative assumptions are made in order not to underestimate future impacts. The Timescales Group reached a consensus on the fact that the safety case (not necessarily calculations) should cover at least ~ 10^6 years, when meaningful prognosis is possible for well chosen site/design.

An important issue is the argumentation for safety in the very long term because of the limited meaningfulness of some indicators and assessments in the very far future. Complementary lines of evidence or other more qualitative considerations are therefore often given more weight at longer times. These include comparisons with natural situations, arguments for continuing isolation and more qualitative concepts (optimisation and BAT). P. de Preter questioned our ability and responsibility to protect the environment in the very remote future.

Peter de Preter concluded that the range of timescales to be addressed in safety cases presents considerable challenges and that consideration of ethical principles is required. He acknowledged also that competing ethical principles need to be balanced.

The evolving countries' scene in terms of drafting and implementing regulations for long-term safety

Juhani Vira (Posiva Oy, on behalf of Esko Ruokola from STUK) presented the history of the development of regulations for spent fuel disposal in Finland. The government decision 478/1999 introduced safety criteria which depend on the time frames: dose constraints in the first thousands of years, radionuclide release constraints up to 100 000 years and qualitative arguments in the longer time frames. J. Vira stressed the importance of ethical considerations for deriving the regulation. Since these criteria met a wide acceptance it is not felt advisable to revise them in the near future.

Philippe Bodenez (ASN) presented the situation in France. The Dossier 2005 was reviewed on the basis of the RFS III.2.f issued in 1991. The RFS asks for compliance with a strict dose limit for at least 10 000 years. This dose limit becomes a target in the longer time frames. An update of the RFS is underway but there is no intention to change the safety criteria. International consensus on the biosphere and on the operational safety are important issues.

Klaus Röhlig (GRS) presented the ongoing revision of the safety criteria for underground disposal in Germany. They relate to the recent development of international recommendations. This implies the implementation of a stepwise approach to repository development with a view to optimisation. A set of performance indicators orientated on safety functions are being defined. As far as possible, they focus on system components which are essential for safety and the evolution of which can be predicted with reasonable assurance. Their reference values are derived from natural conditions (e.g. background radiation, natural concentrations).

Takaaki Kurasaki (NISA) and Hiroyuki Umeki (JAEA) presented the situation in Japan. T. Kurasaki exposed the Japanese policy on geological disposal and the setting up of a report of a METI subcommittee on the regulatory framework. The retrievability of waste will be maintained until post-closure safety is confirmed. A guide for licensing review will be established before the licensing review itself, which is planned in mid-2020. H. Umeki presented ongoing discussions on the NSC (the

Nuclear Safety Commission) new guidelines for LLW to be disposed in a repository at an intermediate-level depth: risk-informed approach; time frame for the assessment with emphasis on the first few thousand years; three categories of dose criteria based on a disaggregated approach (e.g. the dose constraint for normal evolution is set at 10µSv/yr).

David Bennett (UKEA) presented the situation in the United Kingdom. The guidance and regulation for near surface and geological disposals were issued in 1997. They specify safety criteria based on a risk approach and application of ALARA in the long term. They will be revised in 2008 taking into account developments at the international level.

SESSION 2: THE CHALLENGE FOR REGULATORY POLICY AND DECISION MAKING

Introduction

Janet Kotra (USNRC) introduced Session 2, stating that regulatory policies and decision making are not solely based on technical matters. They should take into account expectations of civil society, international experience, ethical considerations and practical needs of implementers. She introduced the main questions to deal with during the discussion at the end of the session and asked a list of concerns relative to the two first questions.

On the first question: "Is there a shared understanding of risks and burdens from disposal over long and very long times?" she recognised that this leads to another question, "What are the consequences to current and future generations from a failure to decide on workable long-term safety criteria for disposal?"

On the second question: "Which are our duties over time and can we deliver them?" she raised a number of points: do duties remain constant? Is it legitimate to apply varying principles of justice to increasing remote generations and to impose less quantitative measures in the far future? "If duties remain constant, is it reasonable to select different tests for assessing compliance, in a manner appropriate to a given time frame?"

J. Kotra asked the question if regulators can establish tests to provide that 1) duties that can reasonably be discharged are, in fact, performed; 2) remaining duties are transferred as responsibly as possible to subsequent generations in order to offer them maximum flexibility to discharge their duties; 3) transferred burdens (cost, risk, effort) are, at least partially, compensated by transfer of information, resources and continuity of education/skills/research?

J. Kotra stressed that, to be workable, regulatory tests need to communicate clearly and honestly about what is meant by "safety" (i.e. "no harm" is not the same as "no exposure"), promise no more than can be delivered, and provide for safety case information that supports and illuminates safety decisions appropriate for different time frames. It should be possible to demonstrate whether or not compliance is achieved.

Résumé of first day

Klaus Röhlig (GRS) reported the discussions from Session 1 on the issues listed by J. Kotra for further treatment during the workshop.

On the question "Do we have a shared understanding of risk from disposal in the long and very long term?" K. Röhlig reported about the discussion concerning the importance of ensuring the internal consistency of assumptions underlying the assessments and not creating a "fictional world" of consequence assessment. The question "Whom will we protect?" has implications for technical questions. While, as stated by the Timescales Initiative, the use of biosphere stylisations is now generally agreed upon, the issue of geosphere (i.e. upper aquifer) stylisation is less well explored and discussed. The approaches followed during the German criteria development ("get closer to the predictable parts, take nature as yardstick") can be seen as an attempt to avoid inconsistencies, but some deficiencies will remain.

On the question "How do we deal with the ethical question as to the level of protection that may be aimed for as a function of time?" it was stated that the workshop "moves very deliberately into the ethical direction", but – given that ethical positions are by their nature contestable – no agreement was reached about whether this is good or bad. With regard to time perspectives, there exist different pictures about what the general public is concerned about. It needs, however, to be kept in mind that "accepted" does not necessarily mean "ethical". There is a general agreement that one should not impose obligations on future generations (e.g. about water testing), but some assumptions might be possible. It was also stated that there is some question whether waste containment in itself is a good thing for the very long term.

On the question "Is it legitimate to introduce cut-offs?", it was stated that the issue needs to be expanded, given the "never-ending hazard" of the waste but also the need to address chemotoxicity of radioactive as well as of other wastes. A time-dependent choice of indicators and/or criteria is worth discussing. "Limits of practical possibilities" and "Points where optimisation becomes meaningless" are arguments to be considered in the cut-off discussion. This is in line with the findings of the Córdoba workshop and the conclusions of the Timescales initiative and should be further discussed.

On the question of "Did we get enough input to define the meaning of previously undefined terms such as "needs and aspirations", "safety and protection", "future generations", etc. Should these words/concepts be left undefined? Or should they be defined only at some level, e.g. at the national level?" The question arises whether it is really needed to define these terms in order to regulate for long-term safety. It is however necessary to keep the difference between the duty to future generations and the capacity to fulfil it. It might be needed to put the radioactive waste management issue into a broader societal context, connected with the question about what is allowed/accepted/practised in other areas (orphan waste). It should be noted that the Timescales initiative reached no consensus about an appropriate ("ethical") timing of repository closure (minimise burden vs. flexibility).

K. Röhlig concluded that the presentations and, to some extent, the discussion, focused very much on numerical compliance. He asked the question, however, about how important this issue is, given the evolving understanding of the safety case. He reported about the opinion expressed that accounting for recent IAEA guidance is an important issue when it comes to defining a "roadmap" for future work without being too ambitious. In the future, operational issues might become more important. He identified other issues and observations from Session 1. The iterative process with feedbacks between implementers and regulators is important for progress, but also problematic. Regulators should keep their distance when a particular site has to be regulated.

Expectations from society

Prof. A. Blowers (CoRWM, UNITED KINGDOM) observed that the social context within which radioactive waste management is considered has evolved over time. The early period where radioactive waste was a non-issue was succeeded by a period of intense conflict over solutions. The contemporary context is more consensual, in which solutions are sought that are both technically sound and socially acceptable. Among the major issues is that of intergenerational equity embraced in the question: how long can or should our responsibility to the future extend?

He pointed out the differences in timescales. On the one hand, geoscientific timescales are very long term, emphasising the issue of how far into the future it is possible to make predictions about repository safety. By contrast, socio cultural timescales are much shorter, focusing on the foreseeable future of one or two generations and raising the issue of how far into the future we should be concerned.

He listed the primary expectations from society which are: safety and security to alleviate undue burdens to future generations and flexibility in order to enable the future generations to have a stake in decision making. The need to reconcile the two had led to a contemporary emphasis on phased geological disposal incorporating retrievability. However, the long timescales for implementation of disposal provided for sufficient flexibility without the need for retrievability. Future generations would inevitably have some stake in decision making.

Prof. A. Blowers pointed out that society is also concerned with participation in decision making for implementation. The key elements for success are: openness and transparency, staged process, participation, partnership, benefits to enhance the wellbeing of communities and a democratic framework for decision making, including the ratification of key decisions and the right for communities to withdraw from the process up to a predetermined point. This approach for decision making may also have implications for regulators, such as involvement in decision making, greater harmonisation of regulation and integration of societal concerns.

Kjell Andersson (Karita Research, Sweden) presented the expectations of society on regulators based on his experiences, mostly from Sweden. Society expects the regulator to be competent, have integrity, take an active part in participative processes (without losing independence), be the “people’s experts”, communicate standards and criteria so that they are understandable and show their practical meaning. Some good results have been obtained in Sweden with respect to trust in national agencies as witnessed by the results of the Eurobarometer on information on radioactive waste in 2005.

The main issues raised by K. Andersson were: responsibility for future generations, period of regulatory concern, extent of ethical obligations, scenario generation, risk dilution, safety indicators, criteria for optimisation and BAT. These issues are largely of a value-laden and ethical nature. Regulatory criteria and guidelines about them cannot be grounded in science alone. They need to be mediated with public values. The citizens, but also the political decision makers, need to see both the factual and the value-laden components of regulatory guidelines and licensing decisions. One problem is the practical implementation of the regulations which has become an expert task and is not a transparent process.

Regulators have therefore a double role. As experts, grounding their regulations on science, they should follow rules of science. As mediators between politics and civil society they are ultimately responsible to the general public, getting their resources from the state budget.

None of the models of participation that have emerged during recent decades have given us what we are looking for, namely, a system providing society with awareness and accountability. Further work is thus needed to link them to the political and legal systems.

On the question of harmonisation of criteria, K. Andersson asked if the existence of different regulatory standards is a problem or if it simply reflects that regulatory bodies are responsive to citizens’ values, which may be different in various cultural settings.

Evolving expectations from international organisations

Carmen Ruíz-Lopez, Chair of the Regulators’ Forum, presented the evolving international safety and protection guidance framework for radioactive waste disposal.

She stated that the implementation of the geological disposal concept requires a strategy that provides national decision makers with sufficient confidence in the level of long-term safety and protection ultimately achieved. The concept of protection against harm has a broader meaning than radiological protection in terms of risk and dose. It includes the protection of the environment and socio-economic interests of communities.

She recognised that a number of countries have established regulatory criteria already, and others are now discussing what constitutes a proper regulatory test and suitable time frame for judging the safety of long-term disposal. Each regulatory programme seeks to define reasonable tests of repository performance, using protection criteria and safety approaches consistent with the culture, values and expectations of the citizens of the country concerned. This means that there are differences in how protection and safety are addressed in national approaches to regulation and in the bases used for that. However, as was recognised in the Córdoba Workshop, it would be important to reach a minimum level of consistency and be able to explain the differences.

The LTSC group's investigations have identified a number of important contributing factors to national differences, among them the complexity and non-uniformity of the regulatory decision making process across nations, a lack of established consensus on how to characterise and measure protection in the distant future, not fully worked out fundamental ethical issues related to the nature of current societal obligations to the future and, reflecting all of this, international guidance which has been evolving with time and still is in the process of evolution (e.g. the recent ICRP guidance development process).

C. Ruíz-Lopez presented an overview of the development of international guidance from ICRP, IAEA and NEA from the Córdoba workshop up to now, and positions of independent National Advisory Bodies. The evolution of these guidelines over time demonstrates an evolving understanding of long-term implications, with the recognition that dose and risk constraints should not be seen as measures of detriment beyond a few hundred years, the emphasis on sound engineering practices, and the introduction of new concepts and approaches which take into account social and economical aspects (e.g. constrained optimisation, BAT, managerial principles). In its new recommendations, ICRP (draft 2006) recognises, in particular, that decision making processes may depend on other societal concerns and considers that the involvement of all concerned parties is needed to achieve more flexible and sustainable decisions.

There is a recognition that regulating the long-term safety of the disposal of long-lived waste is a difficult task, mainly because of the very long time periods and the ethical duty regarding future generations. It will also be very difficult to demonstrate strict compliance with quantitative criteria. The regulations have to be explained and understood by the public and consequently, it is crucial that regulatory criteria and requirements are formulated in such a way that "demonstration of compliance" is facilitated in a credible manner, and it is important to ensure some level of international consistency on fundamental safety and radiological protection objectives and issues.

C. Ruíz-Lopez concluded it would be necessary to try to explore implications of new regulations and to integrate technical aspects on predictions with ethical views on application of our obligation to future generations. It would be particularly useful to set time frames in relation to barrier functions, as was suggested in Session 1.

Expectations from experts in ethics

Prof. Patricia Fleming, (Creighton College, Omaha, USA), centred her presentation on ethical expectations in regulating safety for future generations. The challenge is to find a just solution, one that provides for a defensible approach to intergenerational equity. The question on equity is about whether we are permitted to treat generations differently and to still meet the demands of justice. And the question must be asked regarding these differences: “In what ways do they make a moral difference?”

She asked the question regarding the exact meaning of the ethical principle “Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.” Some countries have proposed different standards for different time periods, either implicitly or explicitly. In doing so, have they preserved our standards of justice or have they abandoned them?

Prof. Fleming identified six points to provide with some moral maps which might be used to negotiate our way to a just solution to the disposal of nuclear waste.

Point 1: Ethicists disagree about whether we have duties to future generations on the very grounds that are now being used by the nuclear waste community to create multi-level standards across the time span of many generations. Prof. Fleming’s position is that if the future is uncertain, regulators should act more cautiously and provide tighter standards.

Point 2: Ethicists have established reasoned claims that we have duties to future generations. But, they do not develop a *gradation* in the strength of that duty. The standards that are set for the present generation are generally regarded as those which should also be set for near and far future generations.

Point 3: The recent surge in interest in sustainability appears to provide a moral defence of multi-level standards of safety; the use of a continuum of static, strong, weak and minimal principles of justice is used to establish that our duties differ over different time spans. But, use of sustainability ethics does not support the creation of different safety standards.

Point 4: What might allow for multi-levels of standards of safety whereby standards for the future are lowered in favour of resolution of a problem in the present is the moral overriding of needs over interests.

Point 5: Assuming there is no moral overriding of present needs over future aspirations or interest, then a single safety standard should apply across present, near and far future generations. What standard should this be? Is this a wholly arbitrary decision?

Point 6: A distinction between capacity to assume or perform a duty and the strength of the duty itself must be made. The strength of duty itself remains the same, but the capacity to fulfil the duty may justify the shifting of the duty, in this case, from present generations to future generations if capacity increases by virtue of certain uncertainties decreasing with time.

Prof. Bråkenhielm (KASAM and University of Uppsala, Sweden) presented an ethical interpretation of the regulations issued by SSI (Swedish Radiation Protection Authority) and SKI (Swedish Nuclear Power Inspectorate). He identified the utilitarian core of the Swedish regulatory framework, but also identified a number of non-utilitarian elements, for example a number of principles of justice presented in KASAM´s *State-of-the-Art Report* from 2004. Thereby, he also hoped to clarify possible spots of moral silence in the Swedish regulatory framework on nuclear waste.

Seven Principles of a Normative Ethics can be identified: (see for example Karl Popper, *The Open Society and its Enemies*, 1948.)

- The Principle of Utility. Negative utilitarianism considers that an action is right if it – in comparison to all alternative possible actions – realises the least amount of evil or harm for all those affected by the action.

- The Principle of Universalisability. All humans should be treated equally, unless there are morally relevant reasons to treat them differently.
- The Principle of Humanism (ultimately echoing the categorical imperative that living individual and present generations are an end in themselves and not merely as a means to the welfare of others), justifying the interests of the present generation.
- The Minimal Principle of Justice which obliges us to use natural resources (including uranium 238 produced by nuclear reactors) in such a way that we do not threaten any person's – present or future – possibilities of life. This justifies the minimising not only of collective dose, but also of risks for (future) individuals.
- The Weak Principle of Justice which obliges us to use our natural resources in such a way that future generations can satisfy their basic needs including their right to *freedom* and *autonomy*. This justifies the KASAM principle that a repository for nuclear waste should be designed so that it makes controls, corrective measures and retrieval unnecessary but also so that it does not make controls, corrective measures and retrieval impossible.
- The Strong Principle of Justice which requires we use natural resources in such a way that future generations might achieve a quality of life equal to our own. This requires, therefore, that the present generation – benefiting from nuclear power – also take care of the nuclear waste and do not put such burdens on future generations that might diminish their achieving a quality of life equal to ours (= a principle of responsibility/producer pays principle).
- The Do-Not-Postpone Principle, i.e. do not postpone until tomorrow what you can already do today.

Claudio Pescatore (NEA) presented Prof. F. Dermange's (University of Geneva, and member of EKRA-I committee, Switzerland) written contribution. This presentation dealt with the requirement of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management which states that "we should not compromise the ability of future generations to meet their needs and aspirations".

He stressed that needs and aspirations are very difficult to define. The general texts dealing with the subject amount to the expression of desirable common social goals, but in terms that are less normative and binding than what would be required for the regulation of nuclear waste.

Prof. Dermange proposes to clarify the expectation from the regulator by interpreting "needs" as safety and "aspirations" as fairness and social acceptance. These concepts should be placed in a hierarchy. Safety is paramount and must not only be understood as the safety of the present generation, but also that of future generations for as long as radioactive emissions can be dangerous to human beings. Fairness is important but not as much so as safety. Democracy is based on fairness, and the latter should be defended, but only after safety is achieved.

The timescales for radioactive waste management are so long, however, that they exceed the possibilities of our society in terms of stability of political and social institutions and in terms of passing on know-how. Ensuring passive safety – that is, independent of human activity – remains the essential requirement. Fairness has not been forgotten, for the principle that assuring safety should constitute as small a burden as possible on future generations was adopted out of a concern for fairness.

On the timescale of the life expectancy of our democratic institutions (two centuries) – the requirements of safety in the interest of fairness mean that human intervention must be possible, at levels that remain to be defined. On timescales where safety is the only factor it must be ensured in an entirely passive way on the basis of our scientific and technological knowledge. It must be possible to shift at any time from an approach to safety based on human intervention to an approach that is totally independent of any human intervention, without having to marshal any special technological or financial resources.

Expectations from implementers

Enrique Biurrun (DBE) presented the expectations from the implementer. He explained that the implementer needs a framework to successfully develop a repository which means the definition of requirements and guidance (for repository system development, analysis, licences, etc.) as well as the decision-making process (stepwise approach, roles of different players, etc.). He also needs a reasonable stability of the regulatory system. The regulatory framework should be developed in a clear, reasonable and consistent manner. In the context of the long duration of the project (100 years) there will be technological progress. In that context E. Biurrun asked what is the meaning of best practice. How can one deal with judgmental issues in a step-wise approach?

Regulatory criteria and guidance must deal with the repository system for which an iterative process is necessary where dialogue is needed with the regulator despite the need to maintain his independence. The safety case, which is a periodic documentation of the status of the project, must provide a synthesis of the underlying scientific understanding and evidence and becomes part of the design process through feedback.

E. Biurrun pointed out that safety is not calculated or assessed, but designed and built into the repository system (by geological and engineered barriers). He stressed the importance of the operational aspects since the implementer has to build and operate the repository safely. He asked the question: is it "Ethical" to buy "peace of mind" of some stakeholders with casualties of the implementer's staff because of mining accidents if the repository is left open during a phase of reversibility.

The implementer needs dependable criteria, legal security and investment security. He interpreted the "Precautionary principle" as meaning "do it now". Long-lasting solutions are very uncertain. Will we have the money and the technology to do it later? He made some reflections regarding the ethical need to strike a balance between inter- and intra-generational requirements ("think not only about the future generations, but also about the generation on our same boat").

E. Biurrun made some remarks on key questions relative to the German situation. He noticed that different radiological protection criteria exist for radwaste and uranium mining and mill tailings.

Discussions around themes of Session 2

Discussion Item 1: Do we have a shared understanding of what the risk is from disposal in the long and very long term?

Hiroyuki Umeki (JAEA), chairman of IGSC, introduced the subject. He listed the three main points to consider in Discussion Item 1:

- The Time frames Group has found that, for all practical purposes, both high-level waste and spent fuel are never radiologically inert and non-hazardous.
- The Time frames Group has also identified the issue of external exposures (or higher releases) that may take place over very long periods of time.
- The issue of the long-term hazard is germane to long lived ILW and LLW as well.

Different questions were raised on Point 1 such as the definition, the way to deal with and the communications associated with the almost indefinite nature of the hazard, the reason to put the emphasis on radiological hazard when chemical hazard is on a par with it, and the existence of different approaches to regulation for either type of hazard.

On Point 2, the questions are raised on the definition of the long and very long-term risk from the hazard and the risk and benefit in the very long term from "containment"?

H. Umeki identified different points for discussion relative to Item 1. On the basis of a typical graphical representation of the exposure levels associated with one ton of spent fuel as a function of time, he emphasised the need to develop techniques for visualising the comparative and absolute hazard as a function of time and to choose representative indicators of the hazard. He asked what should be the respective role of different actors for communications on the matter (regulator, implementer or even government).

The conclusions from the discussion stressed that there was a failure of communication to policy makers and that the link should be made with disposal of chemical wastes.

Discussion Item 2: How do we deal with the ethical question as to the level of protection that may be aimed for as a function of time?

Auguste Zurkinden (HSK) introduced the subject asking the following questions:

Is sustainability, as currently described in the Joint Convention, Article I(ii), achievable over all timescales ? Can we confidently deliver upon the promise: "to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generation"?

A. Zurkinden stated that he was very confident that the impacts imposed on future generations will not be greater than those permitted for the current one. He supported his positive answer by a list of arguments based on the Swiss situation. The Swiss regulation imposes that the release of radionuclides from a sealed repository subsequent to processes and events reasonably expected to happen, shall at no time give rise to individual doses which exceed 0.1 mSv per year.

A. Zurkinden stressed that this positive answer was fully supported by the review of the safety assessment relative to the Nagra Project Opalinus Clay. The main elements leading to the answer were the following: the fact that the repository is built within a stable geological environment, the thorough evaluation of the possible future evolutions, the estimation of the long-term behaviour of the barriers, and the results of the calculation of the movement of radionuclides and of the potential radiological impacts which show that maximum calculated potential doses are three orders well below the protection objective of 0.1 mSv/a. This result was obtained even under pessimistic assumptions.

The confidence in these results is linked to the water tightness and the stability of the Opalinus Clay layer, which is 180 million years old and went undisturbed through many geological events including the Alpine orogeny.

Even though the full set of regulatory guides issued by HSK is currently under revision in order to adapt it to the new legislation it is not intended to change the protection objective of 0.1 mSv/a. A. Zurkinden recognised, however, that the treatment of extremely long times (more than a million years) is an issue to be discussed.

The discussion that followed stressed that many countries do not have such a favourable situation as Switzerland and that, for instance, in discussions in Sweden focussed on the long-term fate of a repository, it was concluded that the lifetime of the geological barrier may be shorter than in the Swiss case, e.g. due to glacial erosion.

Discussion Item 3: Cut-off in time: how and if to choose any?

Jean-Paul Minon, acting Director-General of ONDRAF, introduced the subject asking the following questions:

- Why cut-offs: because we cannot predict? Because no other human endeavour has taken responsibility for such long time frames?
- Can we take responsibility over the long-term and in what way and to what extent?; e.g. do our obligations to current and near-term generations outweigh our obligations to very distant ones in the future?

J.-P. Minon stated that it is not a real issue since there is no safety basis element for cut-offs. Assessment of compliance should be based on complementary quantitative and qualitative arguments since safety relies on site selection, concept design and quality of construction. Calculations are only virtual. The important thing is the soundness of the engineered system which should be feasible and realistic. Calculations after millions of years are meaningless and cannot demonstrate safety. The important thing is to provide confidence and therefore not promise more than what we can do. Our responsibilities on the impact from a repository in the very far future are not higher than from the impact of a uranium ore deposit.

Discussion Item 4: Questions of terminology

Claudio Pescatore introduced the subject asking the following questions:

- Did we get enough input to define "needs and aspirations", "safety and protection" and "future generations"?
- Should these concepts be left undefined or defined at the national level?

C. Pescatore said that the subject was at the same time easy and difficult since it is easy to find definitions but difficult to find a workable one. Regulatory agencies tend not to define safety especially for geological disposal.

He stressed that no vetted definition of safety exists. The Joint Convention cites the terms but does not define them. The question may be asked whether a definition is needed nationally or internationally.

C. Pescatore listed definitions from the Oxford English Dictionary, which defines "safety" as "freedom from danger or risk". Is it a state of mind or an actual situation? For Prof. Dermange/EKRA-I, safety is a primal need, important for life as we know it (related to the sustainability concept). From the IAEA DS-298 safety is an action. From the IAEA Glossary (Sept. 06) safety is the achievement of a series of technical actions around control of sources.

For ethicists, to the extent that safety is about protection, the latter should be the same for all generations. To the extent it is about control, it varies with our ability to assure control. There is a moral duty to address all generations equally but practical limitations on how well we can discharge this duty as time goes by.

C. Pescatore quoted A. Duncan's statement that the ability to intervene (control) is central to normal regulatory practice and to the concept of safety; relinquishing control requires an act of trust – in the technology and the legal and regulatory systems – taken by the current generation on behalf of future generations. He stressed that decision-making process components can be designed to improve trust as well as institutional factors. The practicability of the measures to be taken for assuring and explaining safety clearly plays a role as well.

The role of the technical regulator is to assure to society that licensed projects and licensees (proponents and operators) will meet their commitments for safety. It is thus necessary for the regulator and society to agree on what is meant by safety. C. Pescatore concluded that several views are possible. The important thing is to derive a workable definition free of other non-workable or undefined concepts such as needs, future generations and control. The discussion document proposes a definition that attempts to overcome those difficulties.

SESSION 3: CONNECTING HIGH-LEVEL PRINCIPLES AND OBJECTIVES WITH PRACTICAL COMPLIANCE CRITERIA

T. Schneider (CEPN, France) introduced the subject. He recalled that evaluation of proposals for geological disposal focuses on radiological hazards and protection of humans since this evaluation is based on comparisons of doses or risks with radiation protection criteria.

The objective of safety assessments is to ensure a high level of confidence that no member of a future generation will be exposed to a dose or risk in excess of present-day regulatory dose or risk constraints. Consideration should be given to risk aversion from aggregating the risk.

There are three essential bases for selection of criteria: comparison with current radiation protection criteria for existing operational facilities, comparison with the variability of background radiation exposures and comparison with the generally accepted risk criteria from conventional activities.

As for the assessment of conformity, T. Schneider raised some key issues: use of dose/risk criteria as limits or targets, judgements to be made about choices of parameters and models, degree of conservatism to be taken into account, formal uncertainty analysis to be included and choice of critical group to be made.

He asked the question if the differences in criteria are significant, since the setting of criteria refers to "the definition of acceptable risk" and the assessment of conformity with the criteria refers to the "definition of reasonable assurance". Concerning this question, the issues to be considered are the following: it is a continuing process, the meaning of the numerical differences may not be significant with regard to safety, there is a need to balance the benefit and the cost of options and societal aspects should be considered.

Richard Ferch, expert to NEA and former member of CNSC, presented a detailed review of regulatory approaches and related issues. He introduced the main features of international guidance. The objective of the ICRP 81 is to protect future generations to at least the same level as current generations. A single dose constraint is given. Nevertheless, the interpretation of the calculated doses that are compared with this constraint changes with time. These doses are considered to be measures of health detriment for the first few hundred years, but only indicators of repository performance at longer timescales. ICRP-81 also recognises the usefulness of alternative or supplementary criteria such as Best Available Techniques (not entailing excessive cost), particularly at long timescales where direct quantitative measures of detriment are unavailable.

In the IAEA WS-R-4: as in ICRP-81 a single criterion is recommended regardless of timescale. However, it is recognised that at long timescales such a criterion is no longer a reasonable basis for decision making. As above, two means of dealing with long timescales are suggested: (a) use of the criteria as targets rather than as hard limits (exceeding the criterion need not result in rejection); and (b) possible replacement of the initial criterion with a different one, namely comparison with natural background levels.

With the exceptions noted here, the national criteria reported in the responses to the Regulators' Forum questionnaire in most countries do not explicitly recognise differences in criteria depending on timescales. The clearest examples of this are in the Swiss and the United Kingdom criteria. Five countries choose explicitly to recognise timescales: Germany (cut-off), Finland (change of indicators and cut-off), France (dose limit and then dose target), Sweden (change of indicators then cut-off) and United States (multi-level dose criteria then cut-off).

There is thus a great lack of consensus among regulators at the level of detailed criteria and requirements. There appears to be little agreement not only on values related to the criteria but also on the basis for criteria (absolute risk; dose based on current radiation protection criteria; or dose based on comparisons to natural levels); on whether and how these criteria should change with timescale; and on how to address sources of uncertainty other than long timescales. This diversity might be because each country has different ultimate safety goals, or it might be that we all have the same underlying goals but choose to approach them by different paths. R. Ferch concluded that the only way to find out, and thus to determine whether the observed differences in criteria are meaningful or superficial, appears to be to seek a common understanding about shared (or unshared) goals at a deeper level than that of the criteria.

Plenary discussion on Session 3

Discussion Item 1: RP criteria at extremely long times: dose, risk and/or other indicators? Constraints/ targets lower than ICRP?

T. Schneider introduced Discussion Item 1. He presented the limits of predictability of the various elements of a repository system which decrease strongly in time, from the host rock to the surface environment and the biosphere. He stressed that the first need for harmonisation between countries is the definition of extremely long timescales, which can range from 10 000 to one million years. He asked the question of the meaning of calculations for various timescales. Should they show a strict compliance with regulatory limits or are they only indicative calculations for a performance assessment?

In the discussion that followed, several consensus points emerged. The dose to an individual of the critical group is not a good indicator at extremely long timescales. Other indicators, such as fluxes of radionuclides, may be used. The selection of these indicators should be in relation to the level of predictability of the different parts of the system. The limit of predictability of the host rock in the range 10^5-10^6 years was stressed which puts limits on the credibility on the assessment beyond these time frames. However the use of these indicators in the regulation may be problematic. How to associate reference values to such indicators? Is natural background a reference value? What is the relation with the level of protection? Some attempts to address the first two questions were mentioned by K. Röhlig when he presented the German draft criteria. The risk indicator seems to be better adapted to the long term than a dose indicator; however, the difficulties associated with the risk approach were emphasised (complexity, risk dilution).

Discussion Item 2: Optimisation: criteria for BAT?

Björn Dverstorp (SSI) introduced Discussion Item 2. He presented a pragmatic view on the role of optimisation and BAT in regulating geological disposal. He stressed that risk analyses for geological repositories will always be associated with uncertainties and it will not be possible to check the results of the performance assessment calculations. Therefore there is a need for additional supporting arguments in the safety case (or license application) to convince the regulator and to support decision making.

In SSI's view (SSI FS 1998:1; 2005:5), requirements on the use of optimisation and BAT are necessary supplements to a risk or dose standard. Both principles focus on the proponent's work on developing the repository system rather than the end results of the safety calculations that should be compared with the standard. Optimisation and BAT are applicable to the whole process of developing a final repository, i.e. all steps from siting, design, construction, operation to closure of the repository. In case of a conflict between BAT and optimisation, measures satisfying BAT take priority.

Three main compliance periods can be identified. In a first period the calculated risk (and environmental impact) is the main compliance measure but the application of optimisation and BAT are important complementary arguments. For the time period beyond 100ka, after a glaciation, risk calculations become more speculative due to large uncertainties and the evaluation of compliance will focus more on the application of BAT than on the uncertain results of a quantitative risk analysis. After 1 million years, after closure of the repository, no calculations are required but a simple analysis of the fate of the repository and the very long-term consequences of concentrating uranium in geological formations may provide an important basis for high-level comparison with alternative waste management options.

It is important that the safety case/licence application contains a road map of the most important BAT considerations, i.e. the ones really affecting safety, throughout the development of the repository system so they can be reviewed and presented to the decision makers.

B. Dverstorp identified the constraints for the application of optimisation, including societal constraints on site selection, economic constraints on the availability of funds and technical constraints linked to the availability of technology and the effectiveness of various measures for enhancing the repository's protective capability.

Examples of remaining issues in developing the concepts of BAT and optimisation for geological disposal include:

- How best to report on optimisation and BAT considerations in a safety case/licence application?
- How to strike an appropriate balance between weight given to BAT/optimisation versus risk and dose calculations for different time periods? This is particularly relevant for situations where the calculated risks and doses are close to the regulatory targets.
- How to define available technique or technique that reasonably can be developed?

The ensuing discussion focused on the exact definition of BAT: the most effective means to protect man and environment which do not lead to excessive costs. The problem of its evolution with time was raised. The strong link of BAT with subsystems criteria was noticed. The question of contradictory optimisation consideration for operational and post-closure safety was also raised. One issue raised by J. Kotra was the question of handling the first hundreds of years. How would BAT play in the question? Is it better to ask for a cold or hot repository?

Discussion Item 3: The long term and the treatment of uncertainties

Bo Strömberg (SKI) introduced Discussion Item 3. The Swedish Nuclear Power Inspectorate's regulation SKIFS 2002:1 states that the most important requirement is that uncertainties are described and handled in a consistent and structured manner. The impact of uncertainties should be evaluated by sensitivity analysis, covering for instance the description of barrier performance and the analyses of consequences to human health and the environment.

The guidelines state that there should be a classification of uncertainties into different categories (e.g. scenario uncertainty, system uncertainty, model uncertainty, and parameter uncertainty).

Uncertainties may be handled in many different ways depending on their character, e.g. eliminate them if possible (site selection), account for them in the design, reduce or constrain them as much as is reasonable (non-destructive testing, more site data, R&D), circumvent them in safety assessment (conservative approach) or accept them but discuss them openly (the regulator may prescribe a stylised approach).

In spite of these efforts, a range of uncertainties related to the extreme complexity of the system in consideration must be handled through conservative simplifying assumptions. A thorough justification of such assumptions is needed, since there may be other implications of such assumptions than those originally envisaged. Finally, some uncertainties are not readily reducible or possible to circumvent but are a consequence of the selection of geological disposal (future human action scenarios, intrusion, etc.). Nevertheless they still need to be analysed and discussed.

The regulatory review should examine several points: is there a good justification for elimination of a particular uncertainty? Does the implementer have a good programme to reduce uncertainties? Are the effects of conservative assumptions taken fully into account? Is there a handling and discussion of those uncertainties that have to be accepted?

SESSION 4: WAY FORWARD

Introduction by Chair

Carmen Ruíz-Lopez, Chair of the Regulators' Forum introduced Session 4. She stated that the purpose of this session is to distil and present the main findings of the workshop, and to draw up a road map with the main lines of the future actions in view of communicating the shared understanding and continuing the discussions on the remarkable open items. She presented the organisation of the session and recalled presentations made during the three preceding sessions of the workshop.

Reports from Session 2

Juhani Vira presented the implementer's report on challenges for regulatory policy and decision making.

The findings of Session 2 put forward a need for changes because of the publication of new international recommendations and guidelines and new safety assessments and an approaching licensing phase. J. Vira stressed the recent emphasis on social aspects, the implementation of new policy concepts (sustainability, stakeholder interaction, etc.) and the publication of new regulations.

He raised the question of the extent to which these changes have implications on the fundamental principles or the national regulations. The ethical bases for the regulations were revisited during the session and their application depends on societal choices. The duty of equitable protection through all time periods is therefore upheld with some reservations on balance between near future and very distant future.

J. Vira emphasised that the capacity for perpetual protection was questioned since the toxicity of the wastes remains practically forever but that the proof of protection is subject to growing uncertainty even if the geological stability could be demonstrated over 1 to 10 million years in some countries.

J. Vira concluded that this limited capacity for perpetual protection should be acknowledged in regulations. He recognised that approaches to handle this situation have already been implemented advising optimisation by studying alternative available options and using the best available technology. Considerations to avoid burdens but leave flexibility to future generations may be reconciled by reversibility and retrievability.

It was emphasised that the discussion in Session 2 showed some difficulties in the application of the principles and the need to clarify the content of some concepts introduced in the regulations. It was acknowledged that the terminology is in some cases vague or ambiguous. J. Vira wondered, however, if that really mattered. Some questions have emerged: "Is a view of safety as an intrinsic property of the system possible?" or "Is safety always dependent on the people concerned?"; "Does harmonisation bring vagueness with it?"

J. Vira recalled the NEA concern about the difficulty to gain public acceptance because of differences in criteria between countries. He stressed that the main difficulty behind harmonisation of regulations is the desire of each country to maintain its reliance on a consistent set of national regulations that reflects the national culture and society. He expressed the concern that harmonisation may have diluting effects on regulations. It was noted that the idea behind the LTSC initiative was seeking consistency rather than harmonisation.

He also stressed the importance of the involvement of the public in the regulation and the importance of the stability of regulation for the public and the implementer.

Allan Duncan provided the regulator's report of Session 2.

A. Duncan acknowledged that the work done by the international bodies (ICRP, IAEA) as presented by Carmen Ruíz-Lopez was of high technical quality but had hardly been mentioned in the context of the current workshop discussion. He stressed in this regard that the NEA work is almost unique in that it is addressing the policy and basic objectives elements of regulation. The advantage of input from a number of ethicists resulted in an important advance in the thinking about regulation of long-lived waste disposal.

He mentioned that Patricia Fleming actually posed two key questions, i.e. "What is the objective?" and "What ought it to be?" However he noticed that the answers are not yet convincing enough in a number of countries. There was a general agreement that in order to gain public confidence these questions should be addressed openly. P. Fleming recognised that the ethical guidance might not be the ultimate determinant of policy since it is usually politicians and policy makers that decide.

It was clear, too, that ethicists do not necessarily agree about such fundamental issues as our duties to future generations. This seems however to be extremely important for the implementers and for the regulators. The fact is that the regulatory cycle was being built without a secure and widely accepted starting point.

Prof. Dermange of Switzerland was reported as being dubious about the merits of considering the "needs and aspirations of future generations" as is done in the Joint Convention. His opinion is that "Sustainable Development" language is actually meaningless for all practical purposes when a very long-term perspective is taken into account.

Andrew Blowers introduced the concepts of geo-scientific and socio-cultural time and seemed to suggest that we have the balance wrong as between protecting the interests of people in the very long term and those in the more immediate timescales. Similar ideas were supported by P. Fleming and E. Biurrun in their presentations.

The issue of "harmonisation" was raised in discussion. It seems that the LTSC group would support "harmonisation" in the sense of developing a common understanding of the policy objectives to be achieved in disposal of long-lived waste. It did not seem that there is much support for trying to force all regulatory systems towards a common model. Experience of general environmental regulation, in the European Union at least, suggests that fundamental objectives are being delivered to a common high standard but that the details of how they are delivered are a function of national culture and psyche, and one could doubt that they may be amenable to harmonisation. This point was raised by Klaus-Jürgen Röhlig in connection with the European waste regulators' feasibility study ("European Pilot Study") whose primary purpose is aimed at sharing experience and opinions on the expectation of the regulator regarding different elements of the safety case at different steps of the development of a radioactive waste disposal facility. The most interesting finding of the study is that although regulatory frameworks differ between countries to some extent, it was recognised that regulatory practice differs too much less an extent.

In regard to clarifying the objectives for disposal of long-lived hazardous wastes, there was some discussion about the incongruity between the relatively short-term objectives accepted for chemotoxic wastes and the very long-term objectives demanded for nuclear wastes. It has to be emphasised that the only merit in pursuing such discussion would be to discover why it is that the public draws such a distinction between apparently analogous hazards.

Report from Session 3

Patrick O'Sullivan (NRG) presented a synthesis of Session 3: Connecting high-level principles and objectives with practical compliance criteria.

Concerning radiation protection criteria at extremely long time frames, he acknowledged that the basis for setting up the criteria depend very much on the country. They may be directly related to the value of the dose constraints of the ICRP 81 but may also be related to the variability of natural background or to the tolerability of risk for society. In all respects the principle of optimisation of protection is applied.

Even though some countries have chosen fixed criteria over all time frames, more and more countries use a cut-off or multiple criteria depending on the time frames (e.g. in Sweden four time frames are distinguished).

Many countries acknowledged that safety indicators complementary to dose and risk may be more adapted to long time frames. These indicators, such as concentrations and fluxes, are particularly useful as indicators of system performance in the far future for a specific site. However it may be problematic to associate reference values to these indicators.

For the issue of potential exposure in the far future the risk approach is better suited than the deterministic approach; however it may only be used to the extent that the likelihood of low probability events can be forecast and the issue of risk dilution is taken care of.

There are different views on how much harmonisation of criteria is needed. The main current opinion is to learn from differences, against a "common" background of understanding. It is generally thought that the level of safety provided should not depend on national differences in criteria.

P. O'Sullivan summed up the results on the discussion on optimisation. For ICRP, optimisation is a complementary requirement to dose/risk standards. The subject of optimisation and the application of BAT, defined as the best available techniques not entailing excessive costs, were thoroughly presented and discussed. BAT has the advantage over optimisation of risk in that it concentrates on the performance of barriers and is connected to the application of sound engineering principles as recommended by the ICRP. The question was raised regarding the need for regulatory guidance on the subject, since the regulator cannot foresee precisely what will arise in the proponent's safety case. It was stressed that BAT may be linked to the development of sub-system criteria.

P. O'Sullivan summed up the situation on the handling of uncertainties. It is a fundamental component of the safety assessment in the step-wise approach and is an important contribution to public confidence.

P. O'Sullivan drew some general conclusions from the discussions. The greater the focus on optimisation/BAT – rather than compliance with the dose/risk constraint over long time frames – the less important are the variations in the criteria used by different countries. He stressed the importance of having a good system understanding, i.e. a good level of confidence in the safety case assumptions. Concerning harmonisation, it is important to have agreement on overarching objectives, but the flexibility in implementation (national criteria, etc.) is still necessary. The technical community needs to take account of stakeholders' perspectives: assessment of confidence needs to address the needs of stakeholders (e.g. the ultimate fate of the repository).

FINAL FINDINGS AND ROAD MAP FOR FUTURE ACTIONS

David Bennett, vice-chair of the RWMC Regulators' Forum, delivered the final findings of the workshop and a road map for future actions.

He emphasised that considerable material has been discussed which allows us already to identify some major differences between countries, but also areas of agreement. He recognised that many outputs from the Córdoba workshop (1996) are still valid and noticed a consensus around its conclusions. He acknowledged the work performed in the framework of the Regulators' Forum, including the LTSC and the work of other groups or organisations, which have moved forward some issues: IGSC, timescales group and IAEA. He stressed the difficulty of building a "collective opinion" on the subject of RP criteria.

D. Bennett identified the main points of agreement for defining the bases for regulations concerning the hazards relative to geological disposal of spent fuel or high-level waste. It is largely recognised that even though there is a dramatic early reduction of "hazard potential", residual hazards remain for the very long term (similar to conventional or chemically toxic wastes). All regulators agree that there is a need to provide a high level of protection in the long-term but they have to recognise that what can be demonstrated (capacity) falls short of what they would like to see demonstrated (duty). In the shorter term governments can leave resources to transfer duties as is already happening.

There is also a general agreement on the limitations associated with the long term. In the long time frames we cannot transfer duties nor can we predict or measure long-term impacts.

One should acknowledge the existence of different time frames based on geo-scientific and socio-cultural aspects. Recognising that these different time frames should be treated differently is important. It stresses that cut-offs are important considering the scientific limits on prediction. It shows a pragmatic view, as against absolutist ethical positions.

It is also recognised that regulators should show to other stakeholders that they are fully addressing the question of the remote time frames, and in doing so providing a high level of protection for the long term.

Many aspects contribute to confidence-building. Numerical safety criteria should be defined for periods when safety can be predicted or addressed through stylised assessments. A stepwise approach implies that a regulatory process needs to explain any change in the project. Optimisation and BAT should be implemented in connection with the application of sound engineering and technical standards. Complementary indicators (flux, concentrations, comparisons with background, etc.) are potentially powerful tools in supporting the safety case, and in communicating to wider audiences.

Other points of agreement have been identified. One is the implementers' desire for stability of regulations. Another such point is that sustainability is a difficult principle to apply and that further development of intra-generational and inter-generational equity issues is required.

A list of points requiring further discussion: the nature of the duty to protect future generations (remove burdens but leave flexibilities); the time cut-offs for compliance; the level of harmonisation to reach (dose or risk criteria, although having common origins, may be used differently); the risk approach versus the deterministic approach; the treatment of low probability-high impact scenarios; the use of supplementary indicators and reference levels; and terminology (safety, BAT, others, etc.).

D. Bennett proposed the following road map after the workshop:

The proceedings of the workshop should be published rapidly with session reports. The discussion document should be revised in light of the workshop and published. The workshop has helped develop groundwork towards establishing a "Common Understanding" of the regulation of long-term safety of geologic disposal and the Regulators' Forum needs to take the work forward. There is a need for a future symposium to further develop thinking on focussed aspects.

These points should be taken forward at the RWMC-RF and reported to the RWMC in March 2007.

The scope of the "Common Understanding" document could be the following:

- Update position on output of Córdoba workshop and add more recent developments/international guidance.
- Establish areas of agreement (need to provide long-term safety, minimum consensus on numerical criteria, duties to future generations, concept of transfer of responsibility, stepwise decision making, role of optimisation and BAT, multiple lines of reasoning, complementary indicators and limitations, recognition of uncertainties, importance of stakeholder interactions).
- Explain why numerical criteria may and will differ (national influences on numbers, hard/soft criteria; modelling approaches, etc.)
- Agree on the definitions of some terms, e.g. BAT, safety.

The audience for the "Collective Understanding" document should be wide ranging (policy makers, regulators, implementers and other interested parties.) Can this be done in one document?

Benefits of the "Collective Understanding" document would be to capture the considerable development of ideas and consensus which have occurred over the last 10 years. This document will have a range of uses:

- Explain at high level how long-term safety addressed.
- Inform development of policy, objectives, regulations, guidance.
- Explain why some apparent differences between national criteria are not material: the safety case development and regulatory processes are more important.

Appendix 1

WORKSHOP PROGRAMME

DESCRIPTION OF THE WORKSHOP

Regulatory acceptance criteria – in particular radiological protection criteria for humans and the environment over long timescales – are a prerequisite to the realisation of any underground repository for long-lived radioactive wastes. In many, if not most, countries, these criteria are still in an evolving state, and especially so for geologic disposal of high-level waste and spent fuel.

It has been recognised for many years that differences in criteria among different countries may constitute an additional difficulty for repository proposals to gain broad public acceptance. Nevertheless, the differences between national regulatory criteria continue to exist and, indeed, to increase. While differences are expected to exist in concrete design factors such as geology, engineering and approaches to performance assessment, these appear to be greatly overshadowed by differences of a more abstract nature, namely differences in the choice of appropriate indicators for protection in the long term and differences in the way these indicators are evaluated and interpreted.

The NEA Radioactive Waste Management Committee (RWMC) has been studying these issues for some time, in particular through the work of the IGSC on timescales and of the Regulators' Forum's Long-term Safety Criteria (LTSC) working group. This work has identified a number of factors which contribute to the differences among criteria: among them the complexity and non-uniformity of the regulatory decision-making process; a lack of consensus on how to characterise and measure protection in the distant future; and fundamental ethical issues related to the nature of current society's obligations to the future.

The RWMC considers that it is important to gain a better common understanding of how these differences arise. To this end, the RWMC is sponsoring the present workshop. The intended audience includes a broad range of regulators, implementers, ethicists, and policy makers. A discussion paper based on the findings of the LTSC group and discussions within the RWMC supports the workshop.

In addition to making the work done to date more widely and better known, it is hoped that points of agreement and points for further discussion will be identified, so that a road map may be proposed in support of regulators and policy makers who are currently charged with developing regulatory acceptance criteria for proposed repositories.

28TH NOVEMBER - DAY 1

SESSION 1: SETTING THE SCENE

13:45 Introduction
C.-M. Larsson, Chair

14:00 The Regulatory Framework of Long-Term Safety: the Work of the RWMC Regulators' Forum (RF)

- The RF brochure on the regulatory function with emphasis on decision making
  A. Duncan

N.B.: http://www.nea.fr/html/rmw/reports/2005/nea6041-regulatory-function.pdf

- The Long-term Safety Criteria (LTSC) initiative and the current discussion papers
  C.-M. Larsson, Chair of LTSC initiative

N.B.: Discussion Paper NEA/RWM(2006)13

14:45 Which Were the Issues 10 Years Ago for Regulating Long-Term Safety: the NEA Cordoba Workshop of 1997
A. Hooper

15:00 Relevant Findings from the Timescales Initiative of The IGSC (2006)
P. de Preter, H. Umeki, E. Forinash

15:15 The Evolving Countries' Scene in Terms of Drafting and Implementing Regulation for Long-Term Safety

- 10-minute presentations from a few invited countries highlighting challenges
  Finland: .... *J. Vira*
  France : .... *P. Bodenez*
  Germany: .... *G. Arens*
  Japan (2 presentations):......... *M. Kurasaki* (NISA),
  H. Umeki (Special Committee of NSC)
  United Kingdom: .... *D. Bennett*
- All other countries are invited to provide a 1-pager on this subject, or the Secretariat will check the national Level -1 contribution.

16:30 *Break*

17:00 Plenary Discussion Moderated by Chair
C.-M. Larsson

- Seeking input on morning subjects; confirming elements of next days' sessions; identification of further items.

18:00 *Adjourn*

29TH NOVEMBER - DAY 2

SESSION 2: THE CHALLENGE FOR REGULATORY POLICY AND DECISION MAKING

09:00 Introduction
J. Kotra, Chair

09:10 Résumé of 1st Day Discussion by Rapporteur
K.-J. Röhlig

09:20 Expectations From Society

- Three presentations expected
  United Kingdom, *Prof. A. Blowers*
  Sweden, *K. Andersson*

10:20 *Break*

10:50 Evolving Expectations from International Agreements and Organisations, e.g. the Joint Convention, the ICRP Texts, the IAEA Document and Specialised Fora
C. Ruíz

11:10 Expectations from Experts in Ethics
- *Prof. P. Fleming,* Creighton College (USA)
- *Prof. C.R. Bråkenhielm,* University of Uppsala and KASAM (Sweden)
- *Prof. F. Dermange*[1], University of Geneva and member of EKRA-I (Switzerland)

12:10 Expectations From Implementers
E. Biurrun, P. Zuidema, and others

12:30 ***Lunch***

14:00 Discussion around Themes of Morning Session – Chair
- 4 main discussion items; 30 minutes each.
- Each item is introduced by a 5-minute thought-provoking presentation and followed by a plenary discussion. Materials from the discussion paper are highlighted.

Discussion Item 1:
Do we have a shared understanding of what the risk is from disposal in the long and very long term? *[H. Umeki]*
- The Timeframes Group (TG) has found that, for all practical purposes, both high-level and spent fuel waste are never radiologically inert and non-hazardous.
- The TG has also identified the issue of external exposure (or higher releases) that may take place over very long periods of time.
- The issue of the long-term hazard is germane to long-lived ILW and LLW as well.

Discussion Item 2:
How do we deal with the ethical question as to the level of protection that may be aimed for as a function of time? [*A. Zurkinden*]
Is sustainability, as currently described in the Joint Convention, Article 1(ii), achievable over all timescales?
- Can we confidently deliver upon the promise to avoid “reasonably predictable impacts on future generations greater than those permitted for current generations”? [Joint Convention, Article 4(vi) and 11(vi)]

Discussion Item 3:
Cut-offs in time: how and if to choose any? *[J.-P. Minon]*
- Why cut-offs: because we cannot predict? Because no other human endeavour has taken responsibility for such long time frames?
- Can we take responsibility over the long term and in what way and to what extent? e.g. do our obligations to current and near-term generations outweigh our obligations to very distant ones in the future?

Discussion Item 4:
- Did we get enough input to define the meaning of previously undefined terms such as “needs and aspirations”, “safety and protection”, “future generations”?
- Should these words/concepts be left undefined? Or should they be defined only at some level, e.g. at the national level? *[C. Pescatore]*

16:00 ***Break***

1. Prof. Dermange’s paper will be presented by Dr. C. Pescatore.

SESSION 3:
CONNECTING HIGH-LEVEL PRINCIPLES AND OBJECTIVES WITH PRACTICAL COMPLIANCE CRITERIA

16:30 Introduction
Chair, Th. Schneider

16:40 Detailed Review Of Regulatory Approaches And Attending Issues Based on Annex 3 of the Discussion Paper
R. Ferch

17:00 Plenary Discussion Session around Three Main Themes:

- 3 main discussion items; 30-40 minutes each.
- Each item is introduced by a 5-minute thought-provoking presentation and followed by a plenary discussion. Materials from the discussion paper are highlighted.

Discussion Item 1:

- RP criteria at extremely long times: dose, risk and/or other indicators? Constraints/targets lower than ICRP? [*L. Baekelandt*]

Discussion Item 2:

- Optimisation: Criteria for BAT? Disposal depth… [*B. Dverstorp*]

In each case, why? Technical? Societal? Comparison to other non-RWM practices?

18:00 *Adjourn (continued next day)*

30TH NOVEMBER - DAY 3

CONTINUATION OF SESSION 3:
CONNECTING HIGH-LEVEL PRINCIPLES AND OBJECTIVES WITH PRACTICAL COMPLIANCE CRITERIA

09:00 Discussion Item 3:

- The long term and the treatment of uncertainties
  [*Bo Strömberg*]

SESSION 4:
WAY FORWARD

09:40 Introduction By Chair
C. Ruíz, Chair of RF

09:45
- Two rapporteurs with different backgrounds capture the presentations and discussions from Session 2 (key questions and issues for regulators, points of agreement and disagreement) in consultation with the Session 2 Chair and propose a joint report for discussion. [*A. Duncan + J. Vira*]

10:10 *15 minutes pause*

10:25
- Two rapporteurs with different backgrounds capture the presentations and discussions from Session 3 (key questions and issues for regulators, points of agreement and disagreement) in consultation with the Session 3 Chair and propose a joint report for discussion. [*C-M Larsson + A. Hooper*]

10:55 *Break*

11:15 Final Findings and Road Map for Future Actions
D. Bennett, Vice-Chair of RF

- Points of agreement;
- Points deserving further discussion or development;
- Road Map for future actions in view of communicating our shared understanding and continuing the discussion on outstanding items.

12:00 *Closure of Workshop*

Appendix 2

CONTRIBUTED PAPERS

THE REGULATORY FUNCTION IN RADIOACTIVE WASTE MANAGEMENT

A. Duncan and C. Pescatore
NEA News 2006 – 24.1

Introduction

The first major action of the Radioactive Waste Management Committee Regulators' Forum (RWMC-RF) was to compile information about waste management regulation in 15 NEA member countries, with emphasis on waste disposal. This includes factual information about national policies for radioactive waste management, institutional frameworks, legislative and regulatory frameworks, available guidance, classification and sources of waste, the status of waste management, current issues and related R&D programmes. The resulting report *The regulatory control of radioactive waste management – Overview of 15 member countries*[1] provides an important source of reference for all stakeholders intent on learning about the regulatory functions and practices in these NEA member countries.

The next step has been to produce a brochure[2] with an easily accessible synopsis of this report, in order to provide a quick introduction to regulatory systems and an overview of current arrangements in NEA member countries. The brochure covers the management of radioactive waste from all types of nuclear installations, such as power reactors, research reactors, nuclear fuel cycle facilities, etc, as well as from medical, research and industrial sources and from defence-related sources where appropriate. It presents the national situations during the first half of the year 2005 but does not address the regulatory control of radioactive waste from natural sources. Its main features are summarised below. (As regards currency of information, it may be noted that RWMC-RF members maintain a database of national fact sheets on the regulatory control of radioactive waste management that is updated yearly.[3])

The regulatory cycle

Like most forms of regulation, the regulatory control of radioactive waste management involves a number of elements and a number of bodies associated with their development and delivery. The elements generally associated with a regulatory process constitute a virtuous cycle, with feedback, that embraces the principle of continuous improvement.

These elements start with recognition of a *practice* requiring regulatory control and with development of a *policy* for its implementation. In the case of radioactive waste management, the need was originally seen as being health protection of the general public and workers against the dangers of ionising radiation, and was based on *objectives* and *standards* traceable to the recommendations of the International Commission on Radiological Protection (ICRP). In more recent times, broader environmental, international, social and economic objectives have been recognised with the setting of

1. http://www.oecdbookshop.org/oecd/display.asp?sf1=identifiers&st1=662004011P1
2. http://www.nea.fr/html/rwm/reports/2005/nea6041-regulatory-function.pdf
3. http://www.nea.fr/html/rwm/rf/welcome.html

objectives, standards and guidelines for disposal site selection criteria, waste package requirements, monitoring criteria, etc. The ultimate objective remains to preserve the safety of both the public and the environment.

The establishment of broad policy and essential objectives is followed by *primary, enabling legislation* together with *secondary legislation* involving regulations, rules, ordinances, decrees, arrêtés, etc. Except where these legal elements are judged to be sufficiently detailed, they are usually followed by publication of the standards to be achieved and by guidance on how these legal elements are to be implemented in practice.

Consent to conduct a practice, by way of the provisions of legislation and regulations, is generally through some formal, legal instrument, often described as a *licence* but also, variously, as a permit, authorisation or decree. This contains detailed terms and conditions and is issued to the person or company recognised legally as the operator of the regulated practice. In some cases a licence may cover all aspects of regulation related to the regulated process or activity, from initial planning and development, through matters such as occupational health and safety of workers and accident prevention, to the final act of disposal. In other cases they may address such aspects separately but having regard, of course, to the interactions between them. *Compliance* with the terms and conditions of a licence is then checked by inspection and monitoring of the operator's activities. Cases of non-compliance are often dealt with by way of notices or requirements placed on the operator or by other means, such as education, which may be described collectively as *compliance promotion*. If necessary, non-compliance is subject to some form of *enforcement* action.

All of these activities are accompanied, in most NEA member countries, by an important element of public involvement by way of consultation and exchange of information, and they are invariably supported by R&D programmes. In countries where specific or legal arrangements are made for meeting the costs of the regulated activity, e.g. waste management, an associated element of cost estimation, validation and fund management is involved. Also, where relevant, there are elements of control related to transfrontier shipment of radioactive materials and waste and to international safeguards against nuclear weapon proliferation.

To complete the cycle there are usually arrangements for reviewing the success of a regulatory system and, if necessary, for taking corrective action by way of *feedback* to the licensing stage, or to the controlling legislation. In addition, most regulatory systems involve following up the granting of a licence to ensure that safe performance is being achieved and, if necessary, taking remedial action such as physical intervention for repair or recovery. This is true for regulation of elements of radioactive waste management such as transport, storage, effluent discharge and, perhaps, even the disposal of short-lived waste.

The disposal of long-lived radioactive waste, however, is different from the above activities in that the impacts are unlikely to become apparent until far into the future, if at all. Therefore, such follow up is effectively impossible. This means that any remedial action is unlikely, unless undertaken by future generations on their own initiative. Accordingly, an important conventional component for securing safety is unavailable to current regulatory bodies. Hence, the granting of a licence for disposal of long-lived waste and closure of a repository involves giving up that key element of active control. It depends on the satisfactory assessment of concepts that are designed to be safe, and it actually involves an act of trust in the technology and in the legal and regulatory systems, taken by the current generation on behalf of future generations.[4]

4. This is the subject of further study by the NEA RWMC.

Analysis of regulatory arrangements in NEA member countries

With all the above elements of the regulatory cycle in mind, the RWMC-RF compiled relevant information about national arrangements. This was done on the basis of a standard template designed to address all aspects of regulatory control of radioactive waste management and to facilitate comparison of specific aspects between different countries. For each of the 15 NEA member countries the brochure shows, in tabular form, the authorities associated with of the following aspects:

- Policy, objectives and independent advice.
- Primary and secondary legislation, regulations, etc.
- Standards and guidance.
- Licensing, inspection, enforcement and appeals.
- Public involvement.
- Research and development.
- Cost estimation for establishment of relevant funds.

Other items (e.g. transboundary shipment of waste, nuclear safeguards, etc.). Inevitably, the information is only a very simple representation of any particular element of regulatory infrastructure, and full comparison of radioactive waste management regulation in different NEA member countries requires reference to details in the main compilation of national information. Nevertheless, it clearly identifies national authorities responsible for specific elements of regulation and provides the basis for initial comparison that may help to facilitate communication and exchange of experience. This comparison is presented in the brochure and leads to a number of helpful observations summarised below.

General observations on the roles of regulators

Systems for delivery of all of these legislative or regulatory elements vary from one country to another, and arrangements may vary as between regulation of waste from nuclear sites, from non-nuclear sites such as hospitals, universities, research laboratories, industry, etc. and from national defence establishments. It is clear, however, that there is no unique or best way of arranging such delivery and that it depends on the national constitutional structure, (e.g. federation or single state), structure of legal systems, organisational frameworks and, to a large extent, upon national regulatory culture.

In most cases regulatory decisions emerge after co-ordination of a wide range of relevant and equally authoritative inputs, and involve bodies ranging from central Government to local communities, together with governmental technical authorities and independent advisory bodies or commissions. These technical authorities are most often referred to as the "regulators" or "regulatory bodies" or "safety authorities". It may be seen, also, that there are usually one or more key, or lead, technical authorities charged with the granting of licences (or for advising on their content), for checking compliance with their terms and conditions and, in many cases, for taking enforcement action in cases of non-compliance.

Against this background, the terms "regulator" and "decision maker" need to be placed in the context of the issue that is being addressed, and the decision that needs to be made. In particular, in trying to identify the lead "regulator" for a particular issue it is important to understand the legislative and constitutional structure in the relevant country at a detailed level, as these differ substantially from country to country. It also needs to be understood that these bodies are rarely unconstrained and that, in most NEA member countries, they must have regard to the responsibilities and authority of other bodies, often Government Ministries.

UNDERSTANDING THE DIFFERENCES AMONGST NATIONAL REGULATORY CRITERIA FOR THE LONG-TERM SAFETY OF RADIOACTIVE WASTE DISPOSAL

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Background

Internationally, underground disposal of certain long-lived radioactive wastes such as spent fuel and high-level radioactive waste is the most widely accepted approach to ensure confidence about the long-term protection of future society. Regulatory acceptance criteria, and in particular radiological protection criteria for humans and the environment over long timescales, are a prerequisite to the realisation of any underground repository for these long-lived wastes. A number of countries have established such regulatory criteria, while others are now discussing what constitutes a proper regulatory test and suitable time frame for ensuring the safety of long-term disposal.

Current regulatory criteria are meant to assure protection and safety for periods of time that are extremely long and are atypical and in advance of other regulation for hazardous materials. Because of differences in attitudes towards safety and towards the methods by which protection is established and assured in different societies, it is not surprising that national differences exist among these criteria. On the other hand, it has been recognised for many years now that national differences in criteria may make it difficult to establish the necessary levels of acceptance of national repository proposals. It is thus important that the differences can be understood and explained.

In 1997, an NEA international workshop was held in Córdoba, Spain, on "Regulating the Long-term Safety of Radioactive Waste Disposal." The conclusions of this workshop included, among others, a reference to the need for clearer guidance on basic dose/risk targets, limits and indicators, and on the meaning of risk in the context of safety assessment and regulation. These conclusions were incorporated into the NEA's programme of work. Subsequently, under the auspices of the NEA Radioactive Waste Management Committee (RWMC), two initiatives were undertaken to study and compare the ways in which a suitable level of confidence is attained in different countries. One of these is the Timescales initiative of the Integration Group on the Safety Case (IGSC), which focuses on the technical arguments by which safety is demonstrated over the long timescales involved. The other is the RWMC Regulators Forum's Long-term Safety Criteria (LTSC) initiative, which looks at the bases of current long-term safety regulation and their applicability. Although these two initiatives deal with different aspects of the demonstration of safety, there is considerable overlap and convergence of the results achieved to date.

When the Regulators' Forum of the RWMC was formed in 1999, one of its first tasks was to review the arrangements in member countries for regulation of radioactive waste management. This work resulted in a comparative study of regulatory structures in member countries.[1] One part of the

1. http://www.nea.fr/html/rwm/reports/2005/nea6041-regulatory-function.pdf.

work leading to this comparative study was a review of the long-term radiological protection criteria for disposal of long-lived waste, and an examination of their consistency amongst countries. After this initial comparison, which revealed a broad range of differing criteria and practices, a follow-up initiative on Long-term Safety Criteria was undertaken, and a group was formed to examine this question in more detail. The objective of this still ongoing initiative is neither to set nor to judge existing standards, but rather to study the criteria used by various member countries and to provide a forum for discussion. Ultimately, it is hoped that this will help provide guidance and information to those programmes still developing criteria, and assist national programmes in communicating the context and meaning of regulatory standards for long-term disposal.

How regulatory criteria differ

Although regulatory criteria for long-term safety normally address several aspects related to safety and protection, the focus of the group's work was initially on radiological (dose and/or risk) criteria. The group found significant numerical differences among the criteria, ranging over roughly two orders of magnitude. The differences are due, in some part, to concrete differences in technical factors such as geology and engineering approaches to both design and performance assessment. These technical differences appear to be greatly overshadowed, however, by differences of a more cultural nature, namely differing attitudes towards the questions of establishing and interpreting safety-related targets, criteria and margins of safety. These cultural differences are reflected in differences in the choice of appropriate indicators for protection in the long term, differences in the ways numerical criteria are applied, and different expectations regarding the desired level of confidence in the calculations. Regardless of these differences, the criteria used in all countries are well below levels at which actual effects of radiological exposure could be observed either directly or statistically.

The LTSC group found that the fundamental bases for long-term radiological protection criteria varies among member countries, with at least three differing approaches observed. Of these approaches, two are based on radiological dose criteria, with one approach using criteria derived from the dose limits and constraints that are used for current practices, and the other approach using criteria derived from arguments related to naturally-occurring levels of background radiation. The third approach rests directly upon the concept of acceptable levels of risk, without direct reference to radiological dose criteria. Of course, these three fundamental approaches are interrelated, and combinations of them are often used.

In addition to differences at the level of fundamental bases for the criteria, the group also observed the existence of several other factors that lead to differences in numerical criteria among countries. For example, in some cases current dose-constraint criteria are adopted directly, whereas in others the criteria are reduced by an additional factor which may reflect either the possibility of the existence of multiple sources of exposure as time elapses or increasing uncertainties in the calculations at more distant times. Criteria based on background-dose rates may either rest on direct comparisons to existing, natural dose rates, or on comparisons to the observed variability in those dose rates. When risk criteria are used, the calculations are used to produce an aggregated risk number in some cases while, in others cases, the probabilities and consequences are left disaggregated.

It is generally recognised that the outcomes of calculations of radiological doses received by future populations are best regarded not as predictions of actual impacts, but rather as somewhat stylised performance indicators. However, when used as the basis for regulatory decision making, in some cases the regulatory criteria are used as limits in much the same way as they are used for current practices. In other cases, the regulatory criteria are used as targets rather than as firm limits.

From the point of view of implementing those criteria and decision making, differences also exist at a less explicit and, therefore, less obvious level. Thus, even when similar computational models are used, the assumptions and data that are used in these models may vary depending on whether the calculations are viewed – by choice or regulatory demand – as "best-estimate" calculations of future impacts, as "conservative" safety analyses for licensing, or as attempts to provide an upper bound on the possible consequences. These differences in the expected or intended role of the analyses are often accompanied by differences in the treatment of uncertainties in data, models and numerical techniques.

For all of these reasons, a simple numerical comparison of criteria listed in a table can be highly misleading, if not meaningless, in order to compare required levels of safety. In its ongoing work, the LTSC group has therefore focused on some of the more fundamental reasons behind the differences among national criteria for long-term safety of radioactive waste, rather than on the numerical criteria themselves.

Some deeper reasons for the apparent discrepancy

While considering the underlying reasons for the current differences in criteria, the LTSC group's investigations identified a number of important contributing factors, among them the complexity and non-uniformity of the regulatory decision-making process, a lack of consensus on how to characterise and measure protection in the distant future, and fundamental ethical issues related to the nature of current society's obligations to the future. Discussion of these factors led to consideration of such matters as the role of the regulator, the meaning of safety and protection, building confidence in decision making, and ethical issues related to the means by which fairness to future generations should be provided.

The disposal of long-lived radioactive waste differs in significant ways from most practices involving radioactive materials in that by design the impacts, if any, are unlikely to become apparent until far into the future, if at all. Therefore, regulatory follow up after granting of a disposal licence, in order to see that the desired long-term effects are being achieved, is effectively impossible over the full design life of the disposal system. This means that an important conventional component for assuring continued safety is unavailable to regulatory bodies, at least over the majority of the design life of the facility, namely the ability to monitor for non-compliance and take corrective action. Hence an important difference between countries is a result of different views on the meaning of safety in the absence of monitoring and direct control. Safety, as understood technically, is the absence of (or reduced potential for) physical harm resulting from the existence and operation of the system over a given period of time. Harm, in turn, is an impact that is judged, within a social and temporal context, to be unacceptable. Criteria for defining acceptability normally involve value judgments and can change with the context. This judgement may vary from one country to another, and also change with time within a given country. This poses problems for those who are charged with defining criteria to be applied to a repository whose design lifetime is expected to exceed greatly the duration of recorded human history and where contexts may vary greatly.

Any consideration of long-term safety criteria for disposal of radioactive waste inevitably raises questions of intergenerational equity – waste is generated today, beneficiaries are today's consumers of energy, but the waste can potentially impact future generations for a very long time. Initially, the most widely-adopted approach to the ethical question of intergenerational equity was based on the principle, simply stated, that the impacts of actions carried out in the present on future generations should not exceed the levels of impact that are considered acceptable today. More recently, however, thinking with respect to intergenerational equity recognises that as the time frame becomes longer, our ability to guarantee that current limits will be met to an acceptable level of confidence diminishes because of uncertainties not only in the physical and engineering models, but also and more significantly in our ability to predict and influence the behaviour, needs and aspirations of future populations many generations removed from us. In addition, and especially taking current trends towards reversibility and stepwise decision making into account, it is increasingly recognised that the impacts of the present generation's actions on the distant future are likely to be modified by the actions of our more immediate successors.

Current thinking about these ethical obligations is evolving, and such ethical considerations are another factor contributing to differences in national criteria for long-term protection. This is particularly evident when comparing the approaches in different countries to the question of time limits or cut-offs to the application of regulatory criteria, and/or to the use of criteria which depend on the timescale (e.g. different criteria to be applied on different timescales).

Conclusions

Since the granting of a licence for definitive disposal of long-lived waste and closure of a repository involves the ultimate absence of the element of active control, the design objective is passive safety without the requirement for further intervention. This represents a fundamental difference between the regulation of present-day activities and the regulation of disposal. This fundamental difference is reflected to a greater or lesser extent in the regulatory processes and criteria adopted in each country.

The LTSC working group is continuing its investigations on this subject, with the next step being a workshop planned for late November 2006 in Paris. In addition to making the work done to date more widely and better known, it is hoped that points of agreement and points for further discussion will be identified during this workshop, so that a road map for future work may be proposed in support of regulators and policy makers who are currently charged with developing regulatory acceptance criteria for proposed repositories.

WHICH WERE THE ISSUES TEN YEARS AGO FOR "REGULATING THE LONG-TERM SAFETY OF RADIOACTIVE WASTE DISPOSAL": THE NEA CÓRDOBA WORKSHOP

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Abstract

This abstract summarises the issues identified at the workshop "Regulating the Long-term Safety of Radioactive Waste Disposal" held in Córdoba, Spain under the auspices of the three NEA committees, the RWMC, the CRPPH and the CNRA in early 1997. The workshop attracted high-level representatives of policy-making bodies, regulators and implementers and had the benefit of a live case study in the certification process for the USDOE WIPP facility. The workshop was structured around three interfacing themes that are relevant to the topic, viz:

- Radioactive waste disposal criteria.
- Performance assessment.
- Regulatory review process.

Rapporteurs analysed the presentations and discussions at the workshop according to this structure to identify outstanding issues. This paper seeks to record the issues identified in a factual and objective manner, trying to avoid any re-interpretation.

Disposal criteria

There was a great deal of interest in what became characterised as hard versus soft regulation and the role of numerical criteria in that context. The issue identified was that the dose or risk targets, indicators or limits used in the relevant national regulations needed to be placed more clearly in the context of the relevant regulatory approach. The hard approach of having a pass/fail criterion was recognised as having a possible merit of transparency, but the consensus was that numerical criteria for radioactive waste disposal should be considered as references or indicators, addressing the ultimate safety objectives, rather than limits in a legal context.

Given that assessments of repository long-term safety consider potential exposures, it was recognised that risk is in principle a more appropriate criterion than dose. However, it was also recognised that risk is more difficult to understand and apply, particularly when studying its disaggregation into probability and consequence when the probabilities of events or processes occurring in the far future cannot be quantified reliably.

A further issue identified was the need to make a multi-factor safety case that addressed a broader range of factors than the potential exposure of a member of a critical (or potentially exposed) group, and exploration of a number of such factors, including comparison with the do-nothing option, was proposed. The important role of multiple lines of reasoning was also recognised, whereby qualitative information such as that relating to long-term geosphere characteristics should be placed alongside quantitative assessments to show how the ultimate safety objectives are being met.

Regulatory guidance on protection of the environment *per se* was also thought to be necessary and it was recognised that this would be informed by then-current initiatives. There was broad support for the argument that a well-designed and suitably located repository would not have a significant impact on the environment in the far future but that the regulatory framework for testing this position remained to be developed.

The issue of timeframes or time cut-offs received considerable attention. It was generally agreed that the distinction needed to be made between, on the one hand, accepting the moral and ethical responsibility for protecting the well-being of people and the environment far into the future and, on the other, the reliable calculation of radiological doses or risks. It was concluded that there was no safety-related basis for setting definite time cut-off but that in the regulatory context there may be sound, pragmatic reasons for establishing timeframes for the application of numerical criteria. In that event, the basis for setting a time cut-off should be made clear.

Performance assessment

Particularly given the key role of performance assessment in calculating doses or risks for comparison with regulatory criteria, it was emphasised that these are not predictions but rather illustrations of long-term behaviour and safety. Closely related to this is the issue that performance assessment has different purposes at different steps of the repository development process (e.g. system choice, design, site selection, formal licensing, etc.)

Improvements were identified to be required in a number of areas, including:

- Treatment of uncertainty and the elicitation and use of expert judgement.
- Clarification on what is meant by concepts of confidence building and/or reasonable assurance.
- Transparent, auditable presentation of methods and results for the benefit of political decision makers and the public.

Particularly given the discussions on multi-factor safety cases and the need to show how the ultimate safety objectives are being met, the problem was identified that robust (perhaps over-conservative) designs and performance assessments, rather than realistic ones, are often used in the context of judging compliance.

In the area of optimisation, it is important to be clear on its meaning and boundaries in relation to a geological repository system, where optimisation is essentially a matter of common sense rather than a formal application of ALARA-type methods.

Regulatory process

The issues identified in relation to the regulatory process centred on the need for development and publication of clear regulatory review approaches and the associated criteria well ahead of licence application. Specifically, guidance was required on stylised approaches in relation to some long-term scenarios; reference biospheres; and human intrusion. A stepwise approach needs to be established for the process, taking account of the needs of both regulator and implementer for interim steps and decisions.

Summary

The workshop concluded that a common basis exists in terms of the methods used and of the understanding of the main issues. Some issues are relatively generic, for example the need for stylised approaches or decision aids to address uncertainties or the risk concept. Therefore they are amenable to resolution through international studies. Other issues are strongly influenced by national administrative, legal and cultural considerations, so national differences would be expected.

A concluding comment was that international harmonisation makes sense at the level of the overall safety objectives, rather than in detailed regulatory criteria.

RELEVANT FINDINGS FROM THE TIMESCALES INITIATIVE OF THE IGSC (2006)

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This document supports the presentation named above. It represents the final version of the Executive Summary of the "TIMESCALES" report of the IGSC.

A key challenge in the development of safety cases for geological repositories is associated with the long periods of time over which radioactive wastes that are disposed of in repositories remain hazardous. Over such periods, a wide range of events and processes characterised by many different timescales acts on a repository and its environment. These events and processes, their attendant uncertainties, and their possible impacts on repository evolution and performance must be identified, assessed and communicated in a safety case.

The handling of issues related to timescales was discussed at an OECD/NEA[1] workshop held in Paris in 2002 and a short report providing an account of the lessons learnt and issues raised at the workshop, was published in 2004 (NEA, 2004a). There is, however, an evolving understanding regarding the nature of the issues related to timescales and how they should be addressed, which provides the motivation for the present report. The report is based on the analysis of the responses to a questionnaire received from 24 organisations, representing both implementers and regulators from 13 OECD member countries, as well as discussions that took place in several later meetings.

The report is aimed at interested parties that already have some detailed background knowledge of safety assessment methodologies and safety cases, including safety assessment practitioners and regulators, project managers and scientific specialists in relevant disciplines. Its aims are to:

- review the current status and ongoing discussions on the handling of issues related to timescales in the deep geological disposal of long-lived radioactive waste;
- highlight areas of consensus and points of difference between national programmes; and
- determine if there is room for further improvement in methodologies to handle these issues in safety assessment and in building and presenting safety cases.

The handling of issues related to timescales in safety cases is affected by a number of general considerations, which are described first. Three broad areas in the regulation and practice of repository planning and implementation affected by timescales issues are then discussed:

- repository siting and design and the levels of protection required in regulation;
- the planning of pre- and post-closure actions; and
- developing and presenting a safety case.

1. The Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD).

Finally, a synthesis of findings is made, including a review of the statements made in the 2004 "lessons learnt" report in light of the discussions contained in the present report. Many of the issues treated in the course of the project are subject to various interpretations, and remain under discussion in national programmes, as well as internationally. Therefore, the findings in this report should not be viewed as conclusive, but rather as a contribution in moving ahead the debate and understanding the similarities and differences among approaches in national programmes.

General considerations in the handling of issues of timescales

Ethical principles

Given the long timescales over which radioactive waste presents a hazard, decisions taken by humans now and in the near future regarding the management of the waste can have implications for the risks to which generations in the far future may be exposed. There are thus ethical issues to be considered concerning, for example, our duty of care to future generations and the levels of protection that should be provided. Decisions regarding the phased planning and implementation of repositories – particularly whether to close a repository at the earliest practical time or to plan for an extended open period – also have an ethical dimension. This is because they affect the flexibility allowed to future generations in their own decision making as well as the burden of responsibility passed to these generations. Relevant ethical principles, such as intergenerational and intra-generational equity and sustainability, are open to different interpretations and can sometimes compete. The interpretations made and balance struck between competing principles is a matter of judgement and may vary between different countries and stakeholder groups, and remain matters of discussion internationally, e.g. in the Long-term Safety Criteria (LTSC) task group of the OECD/NEA Radioactive Waste Management Committee (RWMC).

Evolution of hazard

The hazard associated with radioactive waste results primarily from the external and internal radiation doses that could arise in the absence of adequate isolation (including shielding) and containment of the waste. Although the radioactivity of the waste declines significantly with time, the presence of very long-lived radionuclides means that the waste may continue to present some level of hazard for extremely long times.

Uncertainty in the evolution of the repository system

Geological repositories are sited and designed to provide protection of man and the environment from the hazard associated with long-lived radioactive waste by containing and isolating the waste. Though the sites and engineered barrier designs are generally chosen for their long-term stability and predictability, repository evolution is nonetheless subject to unavoidable uncertainties that generally increase with time. Furthermore, radiological exposure modes, which are closely related to individual human habits, can be predicted with confidence only in the very short term. The decreasing demands on system performance as a result of the decreasing hazard of the waste partly offset the increasing demands that uncertainties place on safety assessment. Nevertheless, while some hazard may remain for extremely long times, increasing uncertainties mean that there are practical limitations as to how long anything meaningful can be said about the protection provided by any system against the hazard. These limitations should be acknowledged in safety cases.

Stability and predictability of the geological environment

Repository sites are chosen for their geological stability and broad predictability. Although predictions of the evolution of even the most stable sites become uncertain over long enough timescales, many national programmes have identified sites that are believed to be stable and sufficiently predictable over timescales of millions of years or more, based on an understanding of their geological histories over still longer timescales. Others plan to search for such sites. For example, in Germany, any new site selection process is likely to follow the procedure set out by an interdisciplinary expert group (Arbeitskreis Auswahlverfahren Endlagerstandorte – AkEnd), which requires the identification of a site having an "isolating rock zone" that will remain intact for at least a million years, based on the normal evolution of the site.

Repository siting and design and the levels of protection required in regulation

In repository siting and in designing complementary engineered barriers, the robustness of the system is a key consideration. Thus, events and processes that could be detrimental to isolation and containment, as well as sources of uncertainty that would hamper the evaluation of repository evolution and performance over relevant timescales, are, as far as reasonably possible, avoided or reduced in magnitude, likelihood or impact.

The isolation of the waste from humans is regarded as an essential role of the geological environment, and must be considered at all times addressed in a safety case. On the other hand, both the geological environment and the engineered barriers can contribute to ensuring that radionuclides are substantially contained, and the roles of the different system components in this regard can vary as a function of time. Most programmes aim for containment of the major part of the radionuclide inventory at least within a few metres from the emplacement horizon and certainly containment in the geological stratum or immediate rock mass where the repository is located, although, in some disposal concepts, more mobile radionuclides, such as ^{36}Cl and ^{129}I, are expected to migrate relatively rapidly (in terms of geological timescales) if released from the repository. The consequences of these and any other releases need to be evaluated.

Regulations specify what needs to be shown, and in some cases over what time frames, in order that a proposed site and design can be considered to offer acceptable levels of protection from this hazard.

The minimum levels of radiological protection required in the regulation of nuclear facilities are usually expressed in terms of quantitative dose or risk criteria. In the case of geological repositories, quantitative criteria apply over time frames of at least 1 000 or 10 000 years and sometimes without time limit. It is, however, recognised in regulations and safety cases that the actual levels of dose and risk, if any, to which future generations are exposed cannot be forecast with certainty over such time frames. Models are used that include certain stylised assumptions, e.g. regarding the biosphere and human lifestyle or actions. Additionally, the "dose" that is being calculated is what radio-protectionists refer to as "potential dose". Hence, the calculated values are to be regarded not as predictions but rather as indicators that are used to test the capability of the system to provide isolation of the waste and containment of radionuclides.

The concept of "constrained optimisation" put forth by the International Commission for Radiological Protection (ICRP) in ICRP-81 is also often a requirement; it is reflected in various terminology but encompasses the concepts in ICRP-81 that a series of technical and managerial principles, such as sound engineering practice and a comprehensive quality assurance programme, are key elements to enhance confidence in long-term safety. For geological repositories, optimisation is generally considered satisfied if all design and implementation decisions have been taken with a view to ensuring robust safety both during operations and after repository closure and if provisions to reduce the possibility and impact from human intrusion have been implemented. In some regulations, alternative or complementary lines of evidence for protection and other more qualitative considerations are required or given more weight beyond 1 000 or 10 000 years, in recognition of the fact that increasing uncertainties may make calculated dose or risk less meaningful.

Generally, although the measures of protection specified in regulations may vary with time, this does not necessarily reflect a view that it is acceptable to expose future generations to levels of dose or risk different to (and higher than) those that are acceptable today. Rather, it reflects practical and technical limitations: in particular, regarding the weight that can be given to results of calculations over such long time frames and the meaning of dose estimates at times when even human evolutionary changes are possible. There is ongoing discussion on the issue of how to define and judge criteria for protection in the furthest future, as a basis for decision making today[2] (see e.g. the ongoing work in RWMC's Long-term Safety Criteria Task Group).

National policies in the planning of pre- and post-closure actions

Current national programmes vary considerably in the degree to which an extended open period prior to the complete backfilling and closure of a repository is foreseen. The ethical principle that future generations should be allowed flexibility in their decision making favours assigning to future generations the decisions regarding backfilling and closure. Early backfilling and closure may, on the other hand, be seen as more consistent with the ethical principle that undue burdens should not be passed on to future generations, and also guards against the possibility of future societal changes, which could lead to lapses in the necessary maintenance and security. Another concern, particularly for repositories in saturated environments, is that detrimental changes to the system may occur or events take place during the open period, and that the severity of these changes or events will increase with the duration of the open period. In such cases, it may be prudent to work towards closure soon after completion of waste disposal. It is, however, recognised that such technical considerations need to be balanced against other factors, such as policies on monitoring and retrievability, which may require a more prolonged open period, or the views of the local community. In any case, it is widely agreed that flexibility regarding the open period should not extend so long as to jeopardise long-term safety.

Monitoring of a wide range of parameters within and around a repository is likely to be carried out prior to repository closure, and some monitoring may take place in the post-closure period. Other post-closure requirements may include passive measures such as record keeping, and active measures such as restricting access to a site. A key consideration in planning such measures is that they should not jeopardise the isolation of the waste and the containment of radionuclides. The planned duration of active measures, including monitoring, varies between programmes, as does the period during which either active or passive measures can be relied upon in a safety case, in particular to deter human intrusion. A cautious approach is generally applied in which no credit is taken for such measures in averting or reducing the likelihood of human intrusion beyond around a few hundred years. This is because of the potential for societal changes and our inability to predict the priorities of future generations. The target time frame for active measures may be longer than this, however, e.g. to improve societal acceptance and confidence. Furthermore, measures that are more passive, such as durable markers or record keeping, may in reality inform future generations about the existence and nature of a repository over periods well in excess of a few hundred years.

Developing and presenting safety cases

In the interests of gaining, sharing and showing understanding of a system as it evolves over long timescales, it is useful to both define and develop means to address various time frames in a scientific and logical manner.

How to deal with generally increasing uncertainties in repository evolution and performance is a key problem to be addressed in developing a safety case. Quantitative safety assessment modelling

2. NEA (2007), *Regulating the Long-term Safety of Geological Disposal, Towards a Common Understanding of the Main Objectives and Bases of Safety Criteria*, OECD, Paris.

tends to focus on potential radionuclide releases from a repository to the biosphere. The uncertainties affecting these models can generally be quantified or bounded and dealt with in safety assessment using, for example, conservatism or evaluating multiple cases spanning the ranges of uncertainty.

Where the consequence of calculated releases is expressed in terms of dose or risk, the biosphere must also be modelled. The biosphere is affected by human activities and relatively fast or unpredictable surface processes, and there is consensus that it is appropriate to carry out biosphere modelling on the basis of "stylised biospheres". That is, representations of the biosphere can be based on assumptions that are acknowledged to be simplified and not necessarily realistic, but are agreed and accepted internationally as valid for modelling studies.

Where regulations do not explicitly specify the time frames over which protection needs to be considered, the implementer has the challenge of deciding on the level and style of assessment to be carried over different time frames, which will then be subject to review by the regulator. Calculations of releases cannot, however, extend indefinitely into the future. Factors to be considered when deciding the time at which to terminate calculations of radionuclide releases include:

- uncertainties in system evolution which generally increase with time;
- the declining radiological toxicity of the waste: as noted above, spent fuel and some other long-lived wastes remain hazardous for extremely long times;
- the time of occurrence of peak calculated doses or risk;
- the need for adequate coverage of very slow long-term processes and infrequent events; and
- the need to address the concerns of stakeholders.

Truncating calculations too early may run the risk of losing information that could, for example, guide possible improvements to the system. Importantly, if the assumptions underlying the models are questionable in a given time frame, then qualifying statements must be made when presenting the results, so that they may be properly interpreted. The time frames covered by modelling in recent safety assessments range from 10 000 years to one hundred million years, although a million years seems to be emerging as a commonly accepted time frame in recent safety assessments.

In considering safety beyond the time frame covered by calculations of release, some programmes have developed arguments based on comparing the radiological toxicity of waste on ingestion with that of natural phenomena (e.g. uranium ore bodies; although the limitations of such arguments are acknowledged). Other lines of argument refer to the geological stability of a well chosen site, which can provide evidence, for example, that uplift and erosion will not lead to exposure of the waste at the surface over timescales of millions of years or more. In practice, a number of different arguments may be presented, and different arguments may provide the most confidence in safety over different timescales, and to different audiences.

In the interests of communicating effectively with stakeholders and to build stakeholder confidence, safety cases need to be presented in a manner that communicates clearly how safety is provided in different time frames. This includes early time frames when substantially complete containment of radionuclides is expected, as well as later times, where some limited releases may occur. Non-specialist audiences are often (though not universally) most concerned about safety at early times – a time frame of the order of a few hundred years after emplacement. Especially when presenting safety cases to such audiences, it can be useful to emphasise the strong arguments for safety in this time frame. It may also be useful to devote a specific section of a safety report to explain the handling of different time frames, how uncertainties are treated (and how this varies with time), how multiple safety and performance indicators are used and how to interpret the results as a function of time.

Refinement of understanding of key issues related to timescales coming from this work

The present document has revisited the various issues discussed in the earlier "lessons learnt" report of 2004, and discussed additional areas such as the planning of pre- and post-closure actions. For some issues, current understanding is unchanged compared to the 2004 document, whereas for others, some differences can be identified.

The timescales over which the safety case needs to be made

The 2004 document argued that ethical considerations imply that the safety implications of a repository need to be assessed for as long as the waste presents a hazard. The present report recognises that there are different and sometimes competing ethical principles that need to be balanced. It seems that the discussion of how to come to a balanced and socially acceptable view is still at an early stage in many nations and internationally. In addition, this discussion should be informed by inputs from a wide range of stakeholders, which is beyond the remit of the working group that produced this report.

The limits to the predictability of the repository and its environment

Both the 2004 document and the present report reflect a view that the limits to the predictability of the repository and its environment need to be acknowledged in safety cases.

Arguments for safety in different time frames

Both the 2004 document and the present report note that the types of argument and indicators of performance and safety used or emphasised may vary between time frames. The present report cites ongoing developments in the approaches to partition future time into discrete time periods and developments in phenomenological and functional analysis in different time frames.

The 2004 document observes that regulations are increasingly providing guidance on the use of lines of argument that are complementary to dose and risk. This observation is confirmed in the present report in the discussions of recent regulations and draft regulations in Sweden and the US. The present document emphasises that complementary lines of argument are required, not only to compensate for increasing uncertainties affecting calculated releases at distant times, but also to address other aspects of safety, especially continuing isolation, even at times beyond when quantitative safety assessments can be supported. Complementary arguments might be based, for example, on the absence of resources that could attract inadvertent human intrusion and on the geological stability of the site, with low rates of uplift and erosion. The argumentation for safety in the very long term is, however, an issue of ongoing discussion that is likely to require a consideration of ethical principles, since it relates to our ability and responsibility to protect the environment in the very remote future.

Interpretation of dose and risk calculated in long-term safety assessments

Both documents note international consensus that doses and risks evaluated in safety assessments are to be interpreted as illustrations of potential impact to stylised, hypothetical individuals based on agreed sets of assumptions. The assumptions are site-specific. Their basis, derivation, and level of conservatism can vary significantly; for this reason, the calculated results from safety cases should be carefully analysed if they are compared among national programmes.

Complementary safety and performance indicators

The 2004 document states that the use of complementary indicators, their weighting in different time frames, as well as reference values for comparison, are issues that may well deserve further regulatory guidance. Recent regulatory guidance cited in the present report shows that safety indicators and requirements are not only quantitative, but can include more qualitative concepts such as best available technique (BAT) and optimisation. This issue of how to evaluate compliance with requirements expressed in terms of qualitative indicators may, however, require further consideration, as may the interpretation of optimisation of protection when dealing with impacts across different timescales.

Addressing public concerns

Both documents note that the period of a few hundred years following emplacement of the waste may deserve particular attention in documents aimed at the public. The present document makes a number of other specific recommendations regarding the communication of how safety is provided in different time frames.

Conclusion

In conclusion, the range of timescales that needs to be addressed within our safety cases presents considerable challenges. The decreasing demands on system performance as a result of the decreasing hazard associated with the waste with time partly offset the demands that increasing uncertainty (and decreasing predictability) place on safety assessment. Nevertheless, as discussed throughout this report, while some hazard may remain for extremely long times, increasing uncertainties mean that there are practical limitations as to how long anything meaningful can be said about the protection provided by any system against these hazards. Thus, time and level of protection – and assurance of safety – are linked to one another. These practical limitations need to be acknowledged in safety cases.

The various methods and approaches discussed in this report demonstrate that there are a range of approaches available now that can be called upon for developing and presenting safety cases. Furthermore, there is room to develop these approaches, for example, taking account of experience gained from stakeholder interactions to develop presentations suited to the needs of less technical audiences.

A general observation from the timescales questionnaire responses is that, in many programmes, a significant part of the final responsibility for the handling of timescales issues in safety cases is assigned to the implementer. Apart from setting safety criteria (that may or may not vary over time), the regulator's task is generally to review and point out any difficulties in the approaches to the handling of timescales issues adopted by the implementer. Wherever the final responsibility lies, a dialogue between the implementer, regulator and other stakeholders is valuable in resolving the issues in a manner that is widely accepted and such dialogue is ongoing in many programmes.

THE PRESENT AND EVOLVING SCENE IN TERMS OF DRAFTING AND IMPLEMENTING REGULATION FOR LONG-TERM SAFETY IN JAPAN

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1. Nuclear Safety Commission of Japan (NSC) – Safety regulation for geological disposal

The drafting of the guides and standards for geological disposal of high-level radioactive waste has been under discussion, with the support of relevant R&D organisations, at the Advisory Board on High-level Radioactive Waste Repository Safety of NSC.

The Japan Atomic Energy Commission has established in its report (April 2006) the technical feasibility of co-disposal of transuranic (TRU) waste and HLW [1]. Following this policy, discussion has started on the amendment of the Final Disposal Act for HLW in 2000 to scope the co-disposal with TRU waste. The NSC discussion on the regulation for long-term safety of geological disposal stays in line with this evolving situation.

In March 2006, the Advisory Board established the following two sub-committees to enhance the discussion about the geological disposal programme which is assumed to last for several decades to final closure of the repository:

1. Sub-committee of institutional consideration; and
2. Sub-committee of environmental requirements for site selection.

The sub-committee of institutional consideration is organised for discussion of applying a stepwise regulation for the safety of the repository at the different stages of the repository closure. It is planned to publish an interim report on basic concept for stepwise regulation in early 2007 after public comment.

The sub-committee of environmental requirements for site selection is discussing the required conditions for selecting detailed investigations areas (DIAs) following the environmental requirements for the selection of preliminary investigation areas (PIAs) which were specified by the advisory board in 2002 [2]. The environmental requirements for DIAs will be provided with reference to the report of the Japan Society of Civil Engineers (JSCE) and state-of-the-art scientific and technical knowledge based on the progress in R&D.

1.1 Intermediate depth disposal project

An intermediate depth disposal project is now proposed by the implementer, Japan Nuclear Fuel Limited (JNFL) for low-level radioactive wastes generated from operation of nuclear power plants with relatively higher radioactivity than those LLW disposed of at near surface repository at Rokkasho. The LLW for intermediate depth disposal also includes the waste generated from the decommissioning of nuclear power plants such as reactor core components, burnable poison, channel box, spent control rods, and spent resin. The intermediate depth repository is based on the multi barrier concept with a depth around 50 to 100 meters below the surface.

For regulating long-term safety of intermediate depth disposal, adopting the risk-informed approach is under discussion. A proposed regulatory framework for radiological protection standard for these wastes is based on a disaggregated approach discussed in the ICRP Publication 81. The idea is to set three dose targets 10 μSv/y, 300 μSv/y, and 10 mSv/y-100 mSv/y, depending on the likelihood of scenarios which are classified in categories as likely, less-likely and very unlikely. These dose values are based on the recommendation of ICRP Publication 81 [3].

Applying the risk-informed approach has been suggested in the NSC report on commonly important issues for safety regulations on disposal of all types of radioactive waste issued in 2004 [4].

2. Nuclear and Industrial Safety Agency (NISA), Ministry of Economy, Trade and Industry, Japan

2.1 Japanese Policy on Geological Disposal

- The Specified Radioactive Waste Final Disposal Act was enacted in 2000.
- The Nuclear Waste Management Organization of Japan (NUMO) will start geological disposal of HLW at a depth of more than 300 m in late 2030s.
- NUMO has been asking all local governments to voluntarily offer candidate sites for preliminary investigations of geological disposal since 2002.
- Relatively high radioactive part of TRU waste will also be disposed of at the same site with HLW.

2.2 Consideration of Regulatory Framework for Geological Disposal

- The Japanese Nuclear Safety Commission (NSC) is now deliberating on the regulatory framework for geological disposal.
- The Radioactive Waste Safety Sub-committee under METI issued the report on the regulatory framework for geological disposal in September 2006, by taking into account:
  - consistency with the NSC report, "The Basic Concept of Regulation on HLW Disposal" in 2000; and
  - consistency with the International Safety Standards, etc.

2.3 Outline of the Report by Radioactive Waste Safety Sub-committee (METI) on the Regulatory Framework for Geological Disposal

Site Selection Phase

- The regulatory organisations will show guidelines for site investigations and review those investigations results conducted by NUMO.

Licensing and Subsequent Regulations

- When issuing a licence for disposal, the regulatory organisations will review the technical feasibility of long-term safety of the repository and the basic concept of safety measures to be taken during the period from designing to decommissioning of the facilities, based on the safety assessment including post-closure phase, which is conducted by NUMO.
- The regulatory organisations will verify the concrete safety measures taken by NUMO through future subsequent regulations.

Design, Construction and Operation Phases

- The regulatory organisations will conduct safety verification of the disposal facilities and radioactive waste packages, in which they will verify compliance with the related technical criteria.
- The regulatory organisations will verify the safety reviews conducted periodically or at the important phases by NUMO, based on the up-to-date geological data and scientific knowledge.

Closure Phase

- Before this phase, the regulatory organisations will verify the safety review for post-closure of the repository conducted by NUMO.
- The regulatory organisations will review and approve the closure measures plan prepared by NUMO, and verify the results of those closure measures.
- The retrievability of waste will be maintained until post-closure safety is confirmed.

Institutional Control

- Long-term post-closure safety of the repository should be ensured by its design and safety measures, and should not depend on institutional controls.
- However, preservation of records and establishment of preservation area by the Government, which are stipulated in the Specified Radioactive Waste Final Disposal Act, may contribute to enhancement of public acceptance and safety.
- Whether a preservation area should be maintained even after dissolution of NUMO will be decided at that time.

References

[1] AEC: Basic concept of geological disposal of long-lived, low-heat generated radioactive waste (TRU waste) – Technical feasibility of co-disposal with high-level radioactive waste, April 2006 (in Japanese).

[2] NSC: Environmental requirements for selection of the Preliminary Investigation Areas for HLW disposal, Nuclear Safety Commission of Japan, September 2002 (in Japanese).

[3] ICRP Publication 81: Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste (1998).

[4] NSC: Commonly important issues for the safety regulations of radioactive waste disposal, Nuclear Safety Commission of Japan, June 2004 (unofficial translation in English).

FINNISH SAFETY CRITERIA FOR GEOLOGICAL DISPOSAL

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The Finnish regulations for the geological disposal of nuclear waste are based on the following generic principles:

- There shall be no future detriments exceeding currently acceptable levels.
- Maximum radiation impacts shall not be higher than those arising from natural radionuclides.
- On a large scale, the average radiation impacts shall be insignificant.

The first principle raises the question, what are the detriments which are currently acceptable. One approach is to consider various risks in man's life, particularly so called societally regulated risks (traffic accidents, occupational hazards…) or risks arising from natural environment. Briefly, a societally-regulated health risk level of 10^{-4}/a is relatively common, a level of 10^{-5}/a raises little concern amongst most people and a level of 10^{-6}/a is really difficult to avoid in modern society. Of environment induced risks, the natural radiation sources represent an average health risk of 10^{-4}/a, and natural disasters cause risks in the range of $10^{-6} – 10^{-5}$ per year in many countries.

By nature, the long-term risks from disposal of nuclear waste are non-voluntary and the waste-generating activity brings forth no direct benefit for the generations in distant future. Spatially the risk is quite limited but, on the other hand, the risk may be very long-lasting. Overall, we deem the acceptable risk from waste disposal should fall in the lower end of the range discussed above and should approach the higher end only in very rare cases.

In the Finnish regulations, the generic principles have been concretised into radiation protection criteria, specified for various timescales as follows:

- An individual dose constraint of 0.1 mSv/a (or equivalent risk constraint for probabilistic events) is given for the time period extending up to several thousand years.
- For the subsequent time period, bringing forth extreme climate changes (glaciation, permafrost), radionuclide-specific release rate constraints (so called geo-bio flux constraints) are given; the fluxes can be averaged over 1 000 years.
- For the time period beyond several hundred thousand years, no rigorous quantitative safety assessments are required as the hazard posed by a geological repository is comparable to that from a natural uranium ore deposit (the repository "naturalises").

The choice of the safety indicators reflects the protection goals. During the first millenia, a high degree of containment is necessary due to the substantial radioactive inventory of waste in the repository. Breach of the containment might result in relatively high radiation exposure of a limited number of people. In that time period, the environmental conditions are reasonably predictable with respect to dose assessments; the reference critical group can be assumed as a self-sustaining community living around the disposal site. Thus the radiation dose, or the dose and the probability of its occurrence in case of unlikely events, is the most appropriate safety indicator.

In the time frame of tens of millenia, substantial degradation of the engineered barrier system cannot be ruled out. The containment and isolation provided by the disposal system should still be effective to ensure adequate protection of the people and the environment. It is prudent to choose a safety indicator which reflects the overall containment and isolation capability of the system rather than any peak releases arising from extreme scenarios.

An aspect to be kept in mind is that the environmental conditions will vary vastly in the very long term. Thus, it is difficult to define an appropriate reference biosphere; adherence to the principle of conservatism may lead to extreme biosphere/critical group scenarios and to misinterpreted protection goals. The concentrate-contain principle implies that while the protection of the public at large may be very good, few people in the future may incidentally receive elevated doses.

In our regulations, these issues have been taken into account by defining the radiation protection constraints as radionuclide specific fluxes. Thus the regulator has taken the burden on considering, what is a reasonable reference biosphere. The regulation also allows averaging of the releases over 1 000 years, i.e. certain time dilution. This is in line with the basic protection goals: regardless of the time dilution the highest potential individual doses will still remain in the range of current exposures from natural sources.

In the time period of a couple of hundred thousand years, the radioactive inventory in spent nuclear fuel becomes equivalent to that in natural uranium from which the fuel was fabricated. Only a few artificial radionuclides remain after that time has elapsed while most of the radionuclides originate from uranium series. In that time frame, safety assessments involve such large uncertainties that demonstration of compliance with quantitative safety criteria becomes questionable. Thus we do not require any rigorous quantitative assessments for the time period beyond about one million years but the judgement of safety can mainly be based on bounding analyses, comparisons with natural analogues, site paleogeology and other less quantitative evaluations.

LONG-TERM SAFETY OF GEOLOGICAL DISPOSAL: PRACTICES IN KOREA

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The 253rd meeting of AEC held on 17 December 2004 issued the "National Radioactive Waste Management Policy" regarding SF management. It can be summarised that the national policy for spent fuel management will be decided later in consideration of the domestic and international technology development. At this time, spent fuels generated in NPPs have been stored within each plant by expanding the storage capacity. And the national policy for spent fuel management including the construction of the interim storage facility for spent fuel shall be timely decided considering the saturation of spent fuel storage capacity from 2016 through national consensus by public consultation among stakeholders.

As a case of the long-lived LILW, long-term radiological safety criteria for long-lived HLW disposal facilities are presented separately for periods of operation and after post-closure. During the operation of radioactive waste disposal facilities, as with other nuclear facilities in operation, the standards for prevention of hazards to the environment as well as dose limits for the general public are to be applied.

Technical standard described at MOST Notice define the technical standards for securing long-term safety incurred from disposal. Performance objectives for the post-closure period of geological repository are set up as radiological risks on individuals of critical groups in future. Annual dose due to normal natural phenomena must not exceed 0.1 mSv as the dose limit. In addition, annual risk due to unpredictable phenomena caused by natural or artificial factors must be restricted to 10^{-6} or less as the risk limit.

The evaluation period for post-closure for HLW geological disposal is not decided in national regulation yet but is expected to be at least 10 000 years and longer. However, when the predicted risk does not reach a maximum value within the period above, verification that the leakage of radioactive materials into the surrounding environment may not increase drastically after the period above and acute radiation risk will not occur to individuals must be duly presented.

For major scenarios that are deemed to affect dose evaluation results considerably as a result of the safety evaluation of disposal facilities, an uncertainty analysis must be conducted. In order to increase the reliability of safety assessment results, the QA principles and related detailed procedures for all stages of the safety evaluation, including the collection and application of input variables, modeling, detailed calculations, and a comprehensive evaluation, must be prepared and applied.

NEW GUIDANCE FOR GEOLOGICAL DISPOSAL OF NUCLEAR WASTE IN SWEDEN

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Abstract

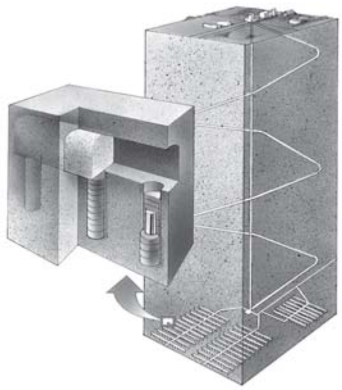
In its recently issued guidance on geological disposal of spent nuclear fuel and nuclear waste the Swedish Radiation Protection Authority (SSI) develops the concepts of the regulatory risk target, best available technique (BAT) and optimisation, and gives recommendations on how to demonstrate compliance with SSI's regulations for different time periods after closure of a geological repository. Because a post-closure risk analysis will always be associated with inescapable uncertainties, the application of BAT is seen as an important complementary requirement to risk calculations. The guidance states that the implementer should be able to motivate all important choices and decisions during the development of a repository, including siting, design, construction and operation, in relation to the repository's long-term protective capability. Although the risk target is in principle independent of time, i.e. the basic premise is that future generations should be given the same protection as today's generation, the guidance acknowledges the increasing difficulty of making meaningful assessments of risk in the distant future. This is reflected in a differentiated expectation in the reporting of compliance arguments: for long-time periods after closure (beyond 100 000 years) more emphasis is given on robust measures of repository performance than on calculated risks that are based on speculative assumptions on, e.g. future climate and human society.

1. Introduction

In 1998 the Swedish Radiation Protection Authority (SSI) issued general regulations [1] concerning the protection of human health and the environment in connection with the final management of spent nuclear fuel and nuclear waste. These regulations are applicable to all types of waste management options, e.g. partitioning and transmutation and launching the waste into space. Since that time the Swedish nuclear waste programme has advanced, and the Swedish Nuclear Fuel and Waste Management Co. (SKB) is now planning to submit a licence application for a deep geological repository for spent nuclear fuel in 2008. The disposal concept entails encapsulation of the spent fuel in copper canisters with a cast iron insert and deposition of these canisters, surrounded by a bentonite clay buffer, at approximately 500 metres depth in crystalline bedrock (Figure 1).

In response to this development, SSI started to develop guidance on how to comply with its regulations [1] for the waste management option geological disposal in 2002. The guidance was issued on 28 September 2005 [2]. In the guidance SSI has developed important aspects of the regulations, including the application of the principles for optimisation and best available technique (BAT), the meaning of the regulatory risk target, protection of the environment and the reporting of calculated risk and other radiation protection arguments for different time periods after closure.

Figure 1. **Illustration of SKB's planned repository for geological disposal of spent nuclear fuel (from SKB's homepage, www.skb.se)**



1.A International review and stakeholder dialogue

In the process of developing the guidance SSI aimed for a broad involvement with representatives from relevant stakeholders as well as national and international experts.

SSI took the initiative to, and together with OECD/NEA, arranged an international workshop on Management of Uncertainty in Safety Cases and the Role of Risk [3]. The outcome of the workshop provided an important basis for further discussions with experts on the international arena on issues like risk dilution and BAT.

In order to increase the transparency and elicit stakeholder views in the process of developing the guidance, SSI also carried out questionnaire studies and arranged seminars and meetings with the general public and politicians from the municipalities currently involved in SKB's programme for siting a spent fuel repository. Specifically, input was sought on the perception of risk and how to value risk in different time perspectives. The public dialogue gave SSI a better understanding of the concerns of the public, which influenced the final drafting of the guidance, for example in the requirements on a detailed account of the consequences of potential early releases and in the guidance on how make the reporting of risk understandable.

2. BAT and optimisation

In order to comply with SSI's regulations, the implementer should, in addition to demonstrating compliance with SSI's risk target, take into consideration possible means of improving the expected performance of the repository system. Optimisation and BAT are two tools to evaluate this and should be used in parallel.

Optimisation is defined as a tool to minimise risk, based on the results of risk calculations. This means that recurrent preliminary safety analyses, carried out by the implementer during the stepwise development of the repository system, should be used to evaluate how, for example, alternative designs of the engineered barriers best contribute to reducing future risks. However, risk analyses for geological repositories will always be associated with uncertainties, especially for long time periods after closure and regarding climate and biosphere conditions, or at early stages of repository development when site-specific data is scarce. Hence, demonstration of safety in an absolute sense is not possible. Therefore the application of BAT is an important complement to optimisation.

BAT focuses on the basic barrier functions of the repository system, aiming to hinder, reduce and delay releases of radioactive substances from both the engineered and the geological barriers and is therefore less sensitive to speculative assumptions on climate and biosphere conditions in the distant future. BAT should be considered at every important step or decision during siting, design, construction and operation of the repository system.

In case of a conflict between BAT and optimisation, measures satisfying BAT should be prioritised. For example, the risk analysis may suggest that a repository solution leading to early releases is acceptable if the radioactive substances are diluted in a large lake or the sea. In such a case a repository solution providing containment, according to the principle of BAT, should be prioritised.

In summary, the use of optimisation and BAT could be seen as an attitude of doing as good job as reasonably possible in creating a safe repository. As in other areas, where BAT and optimisation are applied, the words "reasonably possible" means that due consideration should be given to economical and other societal factors. One example of such societal boundary conditions in the Swedish programme is the voluntary participation in SKB's site investigations on part of the municipalities.

SSI's formal evaluation of compliance with BAT and optimisation will be made when SKB submits a licence application. However, the Swedish system with recurrent reviews of SKB's research and development programme allows SSI to comment on SKB's application of these principles and the way different options have been considered throughout the process leading up to a license application [4].

3. Criteria for the protection of human health and the environment

3.A The risk target

SSI's regulations state that a repository should be designed so that the annual risk of harmful effects (fatal and non-fatal cancer and hereditary defects caused by ionising radiation) should not exceed 10^{-6} for a representative individual in the group exposed to the greatest risk. In the guidance SSI presents different ways to show compliance with this risk target, depending on the size of the exposed group and exposure pathways.

SSI decided to give up the idea of defining the most exposed group geographically or in terms of living habits, i.e. what is commonly known as the critical group concept. The problem is that the exposed group is scenario dependent and, hence, may be very different depending on assumed climate, biosphere conditions, exposure pathways, living habits, etc. Instead the guidance states that the risk analysis should consider the individuals receiving the highest risk and down to one tenth of that risk. If this group consists of a large number of people, the arithmetic average of the individual risks in this group should be used for comparison with the risk target. If there are good arguments for assuming that the group consists of only a few individuals, for example if drinking water from a drilled well is the dominating exposure pathway, the risk target is considered to be met if the highest calculated individual risk does not exceed 10^{-5} per year.

A direct consequence of SSI's definition of the risk target is that the burden of identifying the most exposed individuals largely falls on the implementer. However, additional guidance is given concerning the selection of exposure pathways and assumptions on living habits (see below).

3.B Protection of the environment

According to the regulations, the implementer's safety case should also include an evaluation of possible effects of ionising radiation to the environment. Because there are no comprehensive quantitative criteria available today for assessing environmental effects, the guidance provides general recommendations on the analyses and type of information that SSI expects to see in the implementer's safety case. Organisms to be included in the analysis should be selected on the basis of their importance in the ecosystems, but also with regard to criteria such as their importance for humans in obtaining their livelihood as outlined in the ICRP recommendations [5]. If an impact on key organisms in the environment cannot be ruled out, a closer assessment of possible consequences should be carried out, on the basis of sustainable development and biological diversity. As discussed below organisms and ecosystems in today's biospheres should be used for assessing environmental consequences also in the long term. To allow for an independent regulatory review, and to be able to take into account new findings on radiological effects in the environment, the implementer should also report on concentrations of radioactive substances in soil, sediment and water in relevant ecosystems.

4. Guidance on the risk analysis

In this section we summarise selected parts of SSI's guidance on how to carry out a post-closure risk analysis for a geological repository. Additional guidance, not reported here, concerning safety requirements and safety reporting, is given by the Swedish Nuclear Power Inspectorate (SKI) in their regulations on final disposal [6].

4.A Calculation of risk

The fact that the human health criterion is expressed in the form of annual risk implies that both the probability and the consequences of potential future radiological exposures from the repository have to be taken into account. SSI's guidance does not, however, require a strict probabilistic approach to the risk analysis: both deterministic and probabilistic methods, or combinations of the two, may be used. Nevertheless, probabilistic methods can be foreseen to play an important role, in that they provide a mathematical means of handling the wide range of uncertainties that inevitably will be associated with a post-closure risk assessment.

4.B Averaging of risk over future generations

The very long time periods, thousands to hundreds of thousands of years, that have to be considered in safety and risk analyses for geological disposal of spent nuclear fuel and long-lived nuclear waste, may lead to special problems in the calculation and interpretation of an annual risk. For certain exposure situations, with short duration and large uncertainty as to their occurrence in time, a probabilistic calculation involves an averaging of risk over a large number of future generations. As a result the calculated annual risk from a detrimental event may become very low, even though there is a high probability that a few human generations will become exposed to high radiological consequences, at some point, during the assessment period.

As an idealised example, consider a major earthquake that will rupture the repository and give rise to unacceptably high peak doses over a time period of a few hundred years and that has a probability of close to one to occur some time during the assessment period, say over one 100 000 years. If the earthquake is known, or assumed, to occur at a certain point in time, say 50 000 years after closure, the calculated risk will be unacceptably high for the generations living at that time. On the other hand, if it is assumed that the earthquake may occur at any random point in time between 0 and 100 000 years after closure, the probabilistically calculated annual risk may become almost three orders of magnitude lower because the risk is distributed over hundreds of generations. Hence, only as a result of ignorance concerning the timing of the earthquake, the calculated risk may be significantly reduced.

SSI's guidance defines exposure situations where such risk dilution may occur and provides guidance on complementary deterministic calculations, which should be carried out to enhance the understanding of a probabilistically calculated risk. The objective is to ensure as transparent and comprehensive a decision basis as possible.

If the analyses suggest significant effects of risk dilution, it should be taken as a warning sign that the probabilistically calculated risks may be misleading. However, the problem of how to value possible risk dilution effects in the compliance evaluation has no simple mathematical solution – it is more a philosophical problem related to the definition of risk and who should be protected. Having said this, it can be foreseen that in most cases this type of risk dilution will not become a problem for a deep geological repository. Most foreseeable release scenarios lead to long-lasting releases (over many generations), and dispersive geochemical and hydrological transport processes will further spread out potential peak releases in time.

4.C Selection of natural evolution scenarios

The risk analysis should in principle be based on a comprehensive set of scenarios, which together illustrate the future evolution of the repository's protective capability. However, because any assumption on climate evolution in the distant future will be associated with large irreducible uncertainties, SSI's guidance recommends that the risk analysis be based on a limited number of prescribed climate evolutions, which together illustrate the most important foreseeable climatic disturbances on the repositories' protective capability. For a repository for spent nuclear fuel, which represents a radiological hazard for more than 100 000 years, this means that the effects of both permafrost and glaciations have to be included in the risk analysis.

For each selected climate evolution the repository's protective capability should be evaluated, based on a set of scenarios reflecting the features, events and processes (FEPs) that may affect the evolution of the engineered barriers and the geosphere (the crystalline rock). In order to get a comprehensible risk, mixing of risk contributions from different climate evolutions should be avoided. Instead the risk should be evaluated separately, as a function of time, separately for each climate evolution. The idea being that the repository should be shown to comply with the risk target for each of the analysed climate evolutions, i.e. repository safety should not be dependent on a particular assumed climate evolution.

4.D Future human action (FHA) scenarios

The guidance asks for reporting of FHA scenarios such as inadvertent human intrusion into the repository. The purpose of these scenarios is to illustrate the impact on the repository's protective capability after the human disturbance and to provide a basis for exploring possible measures, e.g. increasing repository depth or avoiding mineral deposits, to reduce the likelihood and consequences of such disturbances, in accordance with the principle of BAT. The reporting of FHA scenarios also has a role in high-level comparisons of alternative waste management options. However, because future human action is a direct consequence of geological disposal, which cannot be completely ruled out, the FHA scenarios should be reported separately and should not be included in the risk calculations.

4.E Exposure pathways and biosphere

The risk calculations may be restricted to a limited number of exposure pathways, but they should be selected so as to represent the diversity of human exploitation of the environment and biological resources that exists in Sweden today. As a general rule, today's biosphere conditions at the repository site and its surroundings, i.e. agricultural land, forest, wetland and mire, lake, etc. should also be used for evaluating radiological risk in the distant future. For assumed future climate states, such as permafrost and glaciations, where today's biosphere is clearly irrelevant, it is sufficient to make a superficial analysis based on today's knowledge of applicable ecosystems.

4.F Cut-off times for the risk analysis

The selection of appropriate time frames for the demonstration of compliance has no exact scientific answer, rather it will have to be based on a combination of scientific reasoning and value judgments. SSI’s criterion for individual risk is expressed as a design target and is not associated with an upper time limit. However, SSI’s guidance reflects the fact that the value of quantitative risk calculations for compliance demonstration will decrease as uncertainties increase with time. SSI gives the following guidance:

1. For repositories for spent nuclear fuel or other long-lived nuclear waste the risk analysis should cover the period of one full glaciation cycle or approximately 100 000 years in order to illustrate the stress on the repository from foreseeable major future climate changes. This time period also coincides with the time at which the radiological toxicity of the spent fuel approaches that of the uranium ore from which it once was produced. For the time period beyond 100 000 years the risk analysis should be extended for as long as it provides useful information on how to improve the protective capability of the repository and at the most up until 1 million years.
2. For other repositories, containing less long-lived waste, it is sufficient to conduct the risk analysis until the time of maximum consequences, and at the most up until 100 000 years.

Table 1**. Summary of SSI’s guidance on reporting and compliance demonstration for different time periods after closure of a geological repository**

<table>
<tr><th>Approximate time periods (years after closure)</th><th>Safety case reporting</th><th>Compliance measures</th></tr>
<tr><td>0 – 1 000</td><td>• Risk analysis based on today’s biosphere
• Special reporting on early barrier transients</td><td rowspan="2">• Calculated risks
• Description of environmental impact
• Application of optimisation and BAT</td></tr>
<tr><td>0 – 100 000</td><td>• Risk analysis based on illustrative scenarios for climate and biosphere
• Complementary safety indicators to support risk calculations</td></tr>
<tr><td>100 000 – 1 000 000</td><td>• Simplified risk analysis
• Analysis of long-term barrier performance and effects of major detrimental events
• Reasoning of protective capability based on risk and complementary safety indicators</td><td>• Application of BAT</td></tr>
<tr><td>> 1 000 000</td><td>• Description of radiological toxicity of the waste*</td><td>• Basis for comparison with alternative waste management methods</td></tr>
</table>

* Reporting requirement in guidance from the Swedish Nuclear Power Inspectorate [6].

5. Reporting and compliance demonstration

In the following we summarise SSI’s guidance on how to demonstrate compliance with SSI’s regulations, i.e. how to present the risk analysis and other radiation protection arguments for different time periods after closure, in the safety case.

The conditions for estimating risks from a geological repository are different for different timescales. Some elements of the risk analysis become speculative already after few hundred years after closure, for example human society and living habits. After a few thousand years the uncertainties regarding the human environment (the biosphere) will increase, which renders calculation of radiation doses and risk even more difficult. In the time perspective of 100 000 years one could expect dramatic climactic changes with glaciations and large sea-level fluctuations in the Scandinavian region. Other elements of the risk analysis, such as the evolution of the basement rock and engineered barriers like the copper canisters in the spent fuel repository, can be expected to be more stable over long time periods. These are some of the considerations behind SSI’s guidance on the reporting of risk analyses and other radiation protection arguments for different time periods, summarised in Table 1 and described in more detail below.

5.A The first thousand years

The first thousand years after closure represent the approximate time period over which a risk analysis can be based on reasonably credible predictions of the climate and biosphere conditions around the repository site. Therefore the guidance states that the risk analysis should be based on site-specific data and descriptions of the biosphere conditions, taking into account known trends such as land rise.

A detailed site-specific description of today's biosphere conditions and ecosystems is motivated by the need to have a good understanding of the consequences of potential early releases, and by the fact that today's biosphere has an important role in assessing radiological protection also in the long term. Early releases are not expected for the planned repository for spent nuclear fuel, but the regulations and guidance apply also to repositories that do not build on complete containment, such as the existing repository for low and intermediate level operational waste at Forsmark in central Sweden.

The guidance also ask for a detailed reporting of transient processes in the early development of the engineered barriers which may affect the long-term protective capability of the repository and, hence, the credibility of the risk analysis. Examples of such processes include the thermal development and resaturation of the bentonite buffer in the planned repository for spent nuclear fuel.

5.B The time period up until 100 000 years

The first 100 000 years after closure represents the approximate time period of one full glaciation cycle. For this time period, SSI expects reporting of calculated risks from the repository. As mentioned above, such calculations will by necessity have to be based on different assumptions, illustrative scenarios, on climate and the conditions in the human environment, already after a few thousand years. The calculated risks should be evaluated against SSI's risk target to determine whether the repository can be expected to provide sufficient protection for future generations. Complementary safety indicators, including measures of barrier performance, activity fluxes in the geosphere and environmental concentrations may, however, be used to strengthen the confidence in the risk calculations. The reporting on the application of optimisation and BAT provide additional compliance measures for this time period.

5.C Beyond 100 000 years

For time periods beyond 100 000 years it is sufficient to report a stylised risk analysis with regard to climate and biosphere conditions. For example, climate change may be treated as a repetition of the first glacial cycle. However, a detailed analysis is expected regarding the long-term development of the basic barrier functions of the repository and the geosphere and on the effects of major external disturbances such as large tectonic events and repeated glacial loads. For these long-time scales uncertainties in the risk calculations are deemed to be too large to base compliance demonstration exclusively on a comparison of calculated risks with the risk target. The compliance discussion may instead be based on a combination of arguments including more robust measures of the repository's protective capability, such as different measures of barrier performance and activity fluxes. Indications of disturbances of the repository's protective capability should be reported together with a discussion on potential measures for improving the repository performance. Hence, for these long time periods SSI's evaluation of compliance will focus more on the application of BAT than on the uncertain results of a quantitative risk analysis.

5.D Beyond one million years

As mentioned above, SSI does not expect any reporting of the risk analysis after one million years after closure. The argument for this is that, after such long time periods, most elements of the risk analysis would be associated with uncertainties too large to make a meaningful assessment of risk. Further, it is hard to foresee any measures that could taken in the design of the repository that would counteract the long-term global geological processes, for example repeated glacial erosion, that eventually may expose the waste to the human environment. However, as indicated in Table I, the guidance [6] by SKI asks for a description of how the radiological toxicity of the waste declines with time. Such reporting of the fate of the repository and the inevitable consequences of geological disposal provide basis for comparison with alternative waste management options.

6. Summary and discussion

SSI has issued guidance on geological disposal of spent nuclear fuel and nuclear waste [2], which outlines a framework for demonstration of compliance with Swedish radiation protection regulations [1]. Key features of the guidance include the parallel use of risk analyses and best available technique (BAT), and differentiated compliance demonstration for different time periods. In the processes of developing the guidance, SSI received valuable input on both technical issues and value judgments through a broad international review and consultation with the municipalities involved in SKB's site investigations for a spent nuclear fuel repository.

Although SSI's regulations specify a quantitative risk standard for geological repositories, which has to be met, there are also complementary compliance arguments for which it is difficult to set up pre-defined quantitative criteria, including the application of optimisation and BAT as well as environmental protection. Consequently, there are still open questions as how to value and weight these complementary lines of arguments in an integrated evaluation of the implementer's safety. Therefore both SSI and the Swedish Nuclear Power Inspectorate have started to develop review plans for the oncoming licence applications, in consultation with both SKB and the involved municipalities [4].

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OVERVIEW ON SWISS REGULATION FOR LONG-TERM SAFETY OF RADIOACTIVE WASTE DISPOSAL

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The Swiss legislation concerning radioactive waste disposal is included in the legislation on nuclear energy. Regarding disposal safety, the following requirements are stated in the new legislation which entered into force on 1 February 2005:

- Radioactive waste shall be disposed of in geologic repositories.
- After the end of waste emplacement, the evolution of the disposal system shall be monitored during a prolonged observation phase.
- Retrieval of the emplaced waste shall be ensured until closure of the repository.
- Closure of the repository shall be ordered by the Federal Council based on a project to be approved by the supervisory authority.
- An underground protection zone shall be established around the repository and registered in the land registry.
- The Federal Council shall ensure that all records concerning the repository (including the waste and the protection zone) are preserved.
- Long-term safety shall be ensured by a system of multiple passive barriers.
- Any measures to facilitate surveillance and repair of the repository or retrieval of the waste shall not impair the functioning of the passive safety barriers.

HSK is charged with developing more specific requirements on disposal facilities in regulatory guides. HSK had already issued long-term protection objectives for the disposal of radioactive waste in the first version of the regulatory guide R-21 in 1980. This regulatory guide was revised in 1993 and is still valid. The safety requirements are expressed in the form of three protection objectives:

PO1: The release of radionuclides from a sealed repository subsequent upon processes and events reasonably expectable to happen, shall at no time give rise to individual doses which exceed 0.1 mSv per year.

PO2: The individual radiological risk of fatality from a sealed repository subsequent upon unlikely processes and events not taken into account in PO1, shall at no time exceed one in a million per year.

PO3: After a repository has been sealed, no further measures shall be necessary to ensure safety. The repository must be designed in such a way that it can be sealed within a few years.

R-21 gives following indications concerning safety assessment:

- Since there is no prescribed cut-off time, calculations should be carried out at least as far in time as the maximum potential consequences.
- The results of calculations concerning the far future are not to be interpreted as effective predictions of radiation exposure of a defined population group. They are indicators for evaluating the impact of a potential release of radionuclides into the biosphere and are compared with the constraints specified in the protection objectives.
- For such calculations, reference biospheres and an affected population with, from a current point of view, realistic living habits should be assumed. The population group most likely to be affected is meant to be a limited number of people. The calculation should pertain to the potential exposure of an average individual of that group.
- Processes and events with extremely low probability of occurrence or with considerably more serious non-radiological consequences, as well as intentional human intrusion into the disposal system, are not required to be considered in the safety assessment.

The full set of regulatory guides issued by HSK is currently under revision in order to adapt it to the new legislation. The revision of R-21 is planned for 2007. We do not intend to change the protection objective of 0.1 mSv/a. However the treatment of extremely long times (more than a million years) is an issue to be discussed.

THE EVOLVING COUNTRIES' SCENE IN TERMS OF DRAFTING AND IMPLEMENTING REGULATION FOR LONG-TERM SAFETY: GERMANY

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The "Act on the Peaceful Utilization of Atomic Energy and the Protection against its Hazards (Atomic Energy Act)" in its most recent version (April 22, 2002) requires "To phase out the use of nuclear energy for the commercial generation of electricity in a structured manner …". Shipments of spent nuclear fuel elements (SNF) from power reactors to reprocessing plants have been banned since July 1, 2005. Disposal of SNF which will arise after that date shall only take place in the form of direct final disposal. Consequently, the volume of heat-generating radioactive waste and operational waste from nuclear power plants as well as the amount of waste from reprocessing to be disposed of is limited, and the total volume of these waste flows arising in Germany can be estimated with relative accuracy. Thus, reliable data relating to the required capacities are available for the planning of waste disposal facilities.

Presently, the management of radioactive waste in Germany is under review. It is the policy of Germany that radioactive material should be concentrated and contained rather than released and dispersed in the environment. According to the international consensus that long-lived radioactive waste has to be disposed of in deep geological formations in order to guarantee that man and the environment are protected in the long run from the effects of ionizing radiation by isolation of the radioactive waste, in Germany **all types of radioactive** waste have to be disposed of in a deep repository.

Amongst the important cornerstones of the new waste management plan is a revision of the Safety Criteria for the disposal of radioactive waste in a mine which were issued in 1983. These presently valid (sub-statutory) Safety Criteria for underground disposal require proof that the site under consideration has favourable mechanical, technical and hydrogeological properties. In order to provide adequate protection of man and the environment, the criteria define the individual dose as the main safety indicator for the post-closure phase. A safety analysis based on models for scenarios postulating a radionuclide release, which cannot completely be excluded, has to be carried out. The analysis has to show that an individual dose limit of 0.3 mSv/a will not be exceeded. In 1988, the Reactor Safety Commission (RSK) and the Commission on Radiological Protection (SSK), which advise the government in technical questions concerning, amongst others, waste management safety, recommended to use the dose criterion for time frames up to 10 000 years but to utilise qualitative arguments for considerations going beyond this time. Nevertheless, this recommendation did not become part of a licensing procedure for repositories.

It should also be noted that the Plan Approval Procedure (i.e. licensing procedure, "Planfeststellung") required by the Atomic Energy Act for federal installations for the safe keeping and final disposal of radioactive waste is in principle a one-step procedure which might last for the whole duration of a project. A stepwise approach is not explicitly implemented. The Plan Approval Procedure has a so-called "concentrating effect" for several fields of law. The still-valid 1983 criteria are tailored for a licensing situation at the end of a Plan Approval Procedure.

The ongoing revision of Safety Criteria is being carried out by GRS on behalf of BMU. It has two objectives:

1. It is intended to update technical criteria according to the state of the art as described in OECD/NEA's Safety Case documents as well as in the IAEA's Safety Requirements WS-R-4 "Geological Disposal of Radioactive Waste". This concerns especially the nature of the Safety Case as a collection of arguments for safety comprising issues such as
   - protection objectives;
   - safety management;
   - safety concept; and
   - safety evaluation/assessment.

2. It is also desired to implement a stepwise approach where, at well-defined decision points, a Safety Case based on the knowledge achieved so far will be compiled, communicated to regulators and other stakeholders and be utilised to support decisions about how to proceed. Such a stepwise approach should form the basis for a process of constrained optimisation in accordance with ICRP and IAEA requirements. The implementation of such an approach in present legislation is, however, considered a challenge. Obviously, its implementation has implications for the formulation of technical criteria mentioned above.

As requested in ICRP-81, the optimisation process has to be carried out in an essentially qualitative way and is to be based on safety-relevant, technical, economic, planning, social and other target functions. With regard to long-term safety, the radiation protection objective to limit the risk for an individual to sustain serious health damage due to exposure to radiation has to be met. In order to ensure this, optimisation is orientated on the objective to improve the confidence in safety and on constraints focusing on the safety functions of confinement and isolation. Namely, the constraints address three issues:

1. **Duration of confinement**: The confinement of the waste has to be ensured over at least 10^6 years.
2. **Completeness of confinement**: The confinement of the waste is considered to be complete if, for likely scenarios, consequences from released radionuclides do not cause a significant increase of consequences from existing, natural conditions.
3. **Dependability of confinement**: The likelihood of scenarios leading to higher releases than the ones mentioned above should be significantly smaller than 1.

The **duration** constraint stems from the work of the German Committee on a Site Selection Procedure for Repository Sites (AKEnd) which concluded that it is possible to identify sites in Germany whose evolution can be predicted over at least 10^6 years and where an "isolating rock zone" can be found which will maintain its properties crucial for confinement (conductivity, thickness, extent, …) over this time frame. This implies that a safety concept has to be developed which emphasises the geologic barrier. It is considered that optimisation becomes meaningless for times beyond the mentioned time frame of predictability.

With regard to the **completeness** constraint it is considered that its assessment should be based on indicators which can be calculated using modelling of components whose evolution can be forecasted over assessment time frame. Consequently, most of the suggested indicators (namely the fraction of released amount of substance, the concentration of released U and Th, contribution of released radionuclides to power density in groundwater, and the contribution to radiotoxicity flux in groundwater) are to be determined in the vicinity of the isolating rock zone. Other indicators (the nuclide concentrations in accessible groundwater and the effective individual dose per year) have a limited, confirmatory meaning. The yardsticks to be used are as far as possible orientated on conditions found in nature; radiological considerations should only be referred to for artificial radionuclides.

Assessing the **dependability of confinement** is a challenge mainly for scenario development and assessment. For scenarios associated with potential releases exceeding the yardsticks mentioned above the likelihood of occurrence for these scenarios has to be assessed in a quantitative way and to be confirmed that this likelihood is significantly lower than 1. If such scenarios cannot be excluded from the assessment on regulatory grounds or because these scenarios are unlikely, their consequences should not exceed those from natural conditions.

Thus, assessment calculations serve as one of multiple lines of evidence substantiating that the optimisation respects the constraints concerning the safety function “confinement/isolation”. It can then be argued that, if the confinement of the waste is ensured, the protection objectives for humans and the environment are met. In turn, the confinement is ensured if the already existing system is perturbed as little as possible. This line of argument is being preferred in comparison to the utilisation of largely hypothetical biosphere models. The discussion about the possibility of “compromising the ability of future generations to meet their needs and aspirations” (Joint Convention) loses importance.

The authors believe that the presented approach accounts for the often required, but less often implemented request to use safety and performance indicators additional to dose or risk. As far as possible indicators are relied upon which can be calculated based on modelling of components whose the evolution can be forecast over the assessment time frame rather than on largely hypothetical biosphere considerations. For times beyond this time frame optimisation becomes meaningless because prediction becomes impossible. As much as possible, the state of the undisturbed system serves as yardstick to evaluate the indicators. This has, however, its limitations with regard to the assessment of potential releases of artificial radionuclides, the assessment of which has to be based on radiological considerations.

CONSIDERATION OF UNLIKELY EVENTS AND UNCERTAINTIES IN THE FINNISH SAFETY REGULATIONS FOR SPENT FUEL DISPOSAL

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1. Introduction

The spent fuel disposal programme in Finland passed in 2001 the decision-in-principle process that is crucial to the selection of the disposal site and to obtaining the political acceptance for the disposal plan. The regulator (STUK) participated in the process by reviewing the implementer's (Posiva) safety case. The review was based on the general safety regulation[1] issued by the Government in 1999 and STUK's guide[2] of 2001 for the long-term safety specifying the general safety regulation. These regulations address also unlikely natural and human scenarios and related uncertainties. The criteria adopted for the judgment of the radiological impact from such scenarios depend on the type of scenario and the time period of concern.

2. General safety regulations

The general safety regulations give a dose-based radiation protection criteria for normal evolution scenarios, which take place during the so-called environmentally predictable future. For normal evolution scenarios occurring beyond that time period, the radiation protection criteria are based on the release rates of disposed radionuclides into the biosphere. The regulations also include specific criteria for dealing with unlikely disruptive events affecting long-term safety and for dealing with uncertainties involved with the assessments. The radiation protection criteria included in the general safety regulations are given below (*in italics*) and discussed in the subsequent chapters.

In an assessment period that is adequately predictable with respect to assessments of human exposure but that shall be extended to at least several thousands of years:

- *the annual effective dose to the most exposed members of the public shall remain below 0.1 mSv; and*
- *the average annual effective doses to other members of the public shall remain insignificantly low.*

Beyond the assessment period referred to above, the average quantities of radioactive substances over long time periods, released from the disposed waste and migrated to the environment, shall remain below the nuclide-specific constraints defined by the Radiation and Nuclear Safety Authority. These constraints shall be defined so that:

- *at their maximum, the radiation impacts arising from disposal can be comparable to those arising from natural radioactive substances; and*
- *on a large scale, the radiation impacts remain insignificantly low.*

1. General regulations for the safety of spent fuel disposal (1999), Government Decision 478/1999 (1999).
2. Long-term safety of disposal of spent nuclear fuel, STUK Guide YVL 8.4 (2001).

The importance to long-term safety of unlikely disruptive events impairing long-term safety shall be assessed and, whenever practicable, the acceptability of the consequences and expectancies of radiation impacts caused by such events shall be evaluated in relation to the respective dose and release rate constraints.

Compliance with long-term radiation protection objectives as well as the suitability of the disposal concept and site shall be justified by means of a safety analysis that addresses both the expected evolutions and unlikely disruptive events impairing long-term safety. The safety analysis shall consist of a numerical analysis based on experimental studies and be complemented by qualitative expert judgement whenever quantitative analyses are not feasible or are too uncertain.

The data and models introduced in the safety analysis shall be based on the best available experimental data and expert judgement. The data and models shall be selected on the basis of conditions that may exist at the disposal site during the assessment period and, taking account of the available investigation methods, they shall be site-specific and mutually consistent. The computational methods shall be selected on the basis that the results of safety analysis, with a high degree of certainty, overestimate the radiation exposure or radioactive release likely to occur. The uncertainties involved with safety analysis and their importance to safety shall be assessed separately.

3. Environmentally predictable future

The regulations define the so-called environmentally predictable future which is assumed to extend up to several thousands of years. During this period, the climate type is expected to remain similar to that nowadays in Northern Europe. However, considerable but predictable environmental changes will occur at the disposal site due to the ongoing land uplift: a seabay will turn into a lake, then into wetland and the sediment might later on be used as farmland. The geosphere is expected to remain quite stable though slight, predictable changes will occur due to the land uplift and the heat generating waste.

In this time frame, the engineered barriers are required to provide almost complete containment of the disposed waste in order to minimise the impacts from waste induced disturbances and to facilitate retrievability of waste. Consequently, people might be exposed to the disposed radioactive substances only as a result of early failures of engineered barriers due, e.g., to fabrication defects or rock movements.

Despite the environmental changes, conservative estimates of human exposure can be done for this time period and accordingly the safety criteria are based on dose constraints. In the STUK guide,[3] the radiation protection criteria are clarified as follows:

The dose constraints apply to radiation exposure of members of the public as a consequence of expected evolution scenarios and which are reasonably predictable with regard to the changes in the environment. Humans are assumed to be exposed to radioactive substances released from the repository, transported to near-surface groundwater bodies and further to watercourses above ground. At least the following potential exposure pathways shall be considered:

- *use of contaminated water as household water;*
- *use of contaminated water for irrigation of plants and for watering animals;*
- *use of contaminated watercourses and relictions.*

3. Long-term safety of disposal of spent nuclear fuel, STUK Guide YVL 8.4 (2001).

Changes in the environment to be considered in applying the dose constraints include at least those arising from land uplift. The climate type as well as the human habits, nutritional needs and metabolism can be assumed to be similar to the current ones.

The constraint for the most exposed individuals, effective dose of 0.1 mSv per year, applies to a self-sustaining family or small village community living in the vicinity of the disposal site, where the highest radiation exposure arises through the pathways discussed above. In the environs of the community, a small lake and shallow water well is assumed to exist.

In addition, assessment of safety shall address the average effective annual doses to larger groups of people, who are living at a regional lake or at a coastal site and are exposed to the radioactive substances transported into these watercourses. The acceptability of these doses depend on the number of exposed people, but they shall not be more than one hundredth-one tenth of the constraint for the most exposed individuals.

The unlikely disruptive events impairing long-term safety shall include at least:

- *boring a deep water well at the disposal site;*
- *core-drilling hitting a waste canister;*
- *a substantial rock movement occurring in the environs of the repository.*

The importance to safety of any such incidental event shall be assessed and whenever practicable, the resulting annual radiation dose or activity release shall be calculated and multiplied by the estimated probability of its occurrence. The expectation value shall be below the radiation dose or activity release constraints given above. If, however, the resulting individual dose might imply deterministic radiation impacts (dose above 0.5 Sv), the order of magnitude estimate for its annual probability of occurrence shall be 10^{-6} at the most.

The radiation protection criteria involve flexibility for the assessment of unlikely disruptive events. Whenever practicable, the assessment should be done in an aggregated way by calculating a radiation dose and the probability of its occurrence and by comparing the resulting expectation values with the respective dose constraints. But the regulations recognise that, due to inherent uncertainties, this is not always feasible and consequently allow also a more disaggregated and less quantitative assessment of consequences and probabilities of unlikely disruptive events.

The regulations specify three unlikely disruptive events that should at least be included in the list of scenarios to be analysed: a deep water well, core drilling and rock movement.

The water well scenario is quite natural because in Finland, tens of thousands of water wells bored at the depth of a couple of tens to hundreds of meters exist. Thus it is quite likely that such a well will exist at the disposal site at some time. The well might short-circuit the transport pathways of contaminated groundwaters and enhance radiation exposure of the critical group.

Considerable uncertainties relate to the analysis of the water well scenario. In order to calculate the arising radiation dose, the dilution factor should be known. Though illustrative analyses give a quite wide range for the dilution factor in case of crystalline rock, a reasonably conservative value can be adopted. The probability of the existence of a water well at the disposal site at a certain time, so that the people using the water are unaware of its radioactive contamination, is more speculative. Nevertheless, the deep water well scenario should be analysed quantitatively, taking into account the involved uncertainties, and the results should be discussed in relation to the radiation dose constraint.

Core drilling, hitting a waste canister, is a very speculative scenario. A reference scenario, preferably an internationally adopted one, should be developed for the analysis of the radiological consequences of such events. Some estimates for probabilities, based on current frequencies of deep drilling, can be obtained, but their projection into the far future is questionable. Because the probabilities are very low and the consequences can even be serious, the core drilling scenario should be assessed in a disaggregated manner.

The rock movement scenario involves an event where a seismic or aseismic phenomenon in the vicinity of the repository causes secondary rock displacements, one of which might intersect waste canisters. In Finland, such events are most likely in postglacial conditions, when the rock stresses induced during ice age are relieved and consequently, the intensities and frequencies of rock movements are by far higher than today. During the past few years, significant progress in the quantitative analysis of probabilities of such events has been achieved. Anyway, large uncertainties are involved with both consequences and probabilities of such scenarios and in the safety assessment, they should be dealt with in a disaggregated manner.

4. Era of extreme climate changes

Beyond about 10 000 years, great climatic changes, such as permafrost and glaciation, will emerge. The range of potential environmental conditions will be very wide and assessments of potential human exposures arising during this time period would involve huge uncertainties. A conservative safety case should be based on extreme bioscenarios and overly pessimistic assumptions.

The climactic changes also significantly affect the conditions in the geosphere, but their ranges are estimable. In this time period, substantial degradation of the engineered barriers cannot be ruled out, though they were planned to withstand the stresses due to the climate-induced disturbances in bedrock. As radionuclide release and transport in the repository and geosphere can be assessed with reasonable assurance, consequently it is prudent to base the radiation protection criteria on constraints for release rates of long-lived radionuclides from geosphere to biosphere (so called geo-bio flux constraints).

In STUK's guide,[4] the general safety criteria addressing the era of extreme climate changes (see Chapter 2) are specified as follows:

The nuclide-specific constraints for the activity releases to the environment are as follows:

- *0.03 GBq/a for the long-lived, alpha emitting radium, thorium, protactinium, plutonium, americium and curium isotopes;*
- *0.1 GBq/a for the nuclides Se-79, I-129 and Np-237;*
- *0.3 GBq/a for the nuclides C-14, Cl-36 and Cs-135 and for the long-lived uranium isotopes;*
- *1 GBq/a for Nb-94 and Sn-126;*
- *3 GBq/a for the nuclide Tc-99;*
- *10 GBq/a for the nuclide Zr-93;*
- *30 GBq/a for the nuclide Ni-59;*
- *100 GBq/a for the nuclides Pd-107 and Sm-151.*

4. Long-term safety of disposal of spent nuclear fuel, STUK Guide YVL 8.4 (2001).

These constraints apply to activity releases which arise from the expected evolution scenarios and which may enter the environment not until after several thousands of years. These activity releases can be averaged over 1 000 years at the most. The sum of the ratios between the nuclide-specific activity releases and the respective constraints shall be less than one.

The release rate constraints have been derived so that they are in general compliance with the dose constraint of 0.1 mSv/a (considering also daughter nuclides), if typical boreal biosphere scenarios are assumed. The rules of application of different kinds of scenarios for the release rate criteria are generally the same as those for the dose criteria (as discussed in Chapter 3). However, it should be noted that the criteria allow the averaging of the releases over 1 000 years at the maximum. This provides a reasonable time dilution of peak releases, similarly as the risk or expectation value concepts do in case of probabilistic events. It also implies that in the very long term, the most important protection goal is not to try to limit incidental peak releases, albeit they might theoretically imply exposures well above the dose constraint, but to provide an effective overall containment of waste.

5. Treatment of uncertainties

According to our regulations, the backbone for the demonstration of the compliance with the long-term safety criteria is a scientifically sound, quantitative safety assessment which should be based on a deterministic, conservative approach, whenever practicable. It is, however, recognised that such rigorous quantitative analyses are not always feasible, and therefore the regulations allow some relaxations. The general regulations for safety assessment, quoted in Chapter 2, are specified in STUK's guide[5] as follows.

In order to assess the release and transport of disposed radioactive substances, conceptual models shall first be drawn up to describe the physical phenomena and processes affecting the performance of each barrier. Besides the modelling of release and transports processes, models are needed to describe the circumstances affecting the performance of barriers. From the conceptual models, the respective calculational models are derived, normally with simplifications. Simplification of the models as well as the determination of input data for them shall be based on the principle that the performance of any barrier will not be overestimated but neither overly underestimated.

The modelling and determination of input data shall be based on the best available experimental knowledge and expert judgement obtained through laboratory experiments, geological investigations and evidence from natural analogues. The models and input data shall be appropriate to the scenario, assessment period and disposal system of interest. The various models and input data shall be mutually consistent, apart from cases where just the simplifications in modelling or the aim of avoiding the overestimation of the performance of barriers implies apparent inconsistency.

The importance to safety of such scenarios that cannot reasonably be assessed by means of quantitative analyses, shall be examined by means of complementary considerations. They may include, e.g. bounding analyses by simplified methods, comparisons with natural analogues or observations of the geological history of the disposal site. The significance of such considerations grows as the assessment period of interest increases, and the judgement of safety beyond one million years can mainly be based on the complementary considerations. Complementary considerations shall also be applied parallel to the actual safety analysis in order to enhance the confidence in results of the whole analysis or a part of it.

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5. Long-term safety of disposal of spent nuclear fuel, STUK Guide YVL 8.4 (2001).

Obviously conservatism in absolute sense is unattainable, given the inherent uncertainties related to the long-term performance of the disposal system. The criteria imply that the result of the analysis (endpoint indicator) with reasonable assurance overestimate really occurring dose or release rate. Our regulations do not explicitly require rigorous quantification of the uncertainties, e.g. in form of confidence levels; rather the implications of uncertainties should be illustrated by means of variant and sensitivity analyses and the confidence in the assessments should be enhanced by complementary considerations referred to above. Thus, though the safety criteria are quite unambiguous, compliance with them cannot be deemed in a straightforward way but will involve abundantly expert judgement.

THE EVOLVING SCENE IN TERMS OF DRAFTING AND IMPLEMENTING REGULATION FOR LONG TERM SAFETY: UNITED KINGDOM NATIONAL REPORT

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Current position

The current UK regulatory requirements for long-term safety of radioactive waste disposal were set out in 1997 in “Disposal Facilities on Land for Low and Intermediate Level Radioactive Wastes: Guidance on Requirements for Authorisation” (the “GRA document”). This was jointly issued by UK disposal regulators and applies to both geological and near surface disposals. It states that:

- Before control is withdrawn, doses to a representative member of the critical group should not exceed a dose constraint of 0.3 mSv/yr.
- After control is withdrawn, the assessed risk to a representative member of the controlled group should be consistent with a risk target of 10^{-6}/yr.
- The best practicable means should be used to ensure that doses and risks are as low as reasonable achievable (ALARA).

The GRA document also states that it is necessary to show that radionuclide releases are unlikely to lead to significant increase in levels of radioactivity in the accessible environment.

Future development

UK disposal regulators recognise that the GRA document needs to be reviewed. Separate guidance will be produced for geological, and for near surface facilities. The review of guidance for geological disposal will consider:

- The issue that the shelf-life for a guidance document of the GRA type is about 10 years at most, whereas the timescale for repository development will be substantially longer.
- The desire that revision of the GRA should not needlessly upset existing packaging standards.
- How control would generally be exercised over a facility for phased geological disposal (i.e. a facility for which backfilling is delayed).
- The implications of various European Directives other than Euratom Directives, e.g. the Waste Framework Directive, the Water Framework Directive and the Landfill Directive.
- International recommendations such as ICRP 81 (on future human actions) and ICRP 91 (on environmental radiation protection) which has been published since 1997.

- The time periods for assessment (there is awareness that some programmes are moving towards shorter time periods for quantitative risk assessment, with more reliance being placed on aspects such as fluxes through the biosphere in the longer term).
- How optimisation should be considered at different stages of the process, potentially conflicting requirements in optimisation, and socio-economic well-being should be considered against health, safety and environmental factors.

The revised guidance will be published in late 2008.

SOCIETAL EXPECTATIONS OF REGULATORS: INTEGRITY, PARTICIPATION AND ACCOUNTABILITY

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During the last two decades the community of nuclear waste management has acknowledged the need for more transparency, stakeholder participation and local community involvement in the decision-making processes. The amount of work done in this area is impressive[1] and the knowledge base has increased dramatically with respect to risk communication, various models of citizen participation, conditions for community involvement and transparency. We have learnt that radioactive waste management, due to its long-term nature, uncertainties, and range of societal impacts, is not the exclusive domain of technical expertise. Wider stakeholder concerns should be addressed at the same level as technical issues. The decision-making process must be open, transparent, fair and participatory. The programmes have also become more communicative by requirements of Environmental Impact Assessment (EIA) at project level and Strategic Environmental Assessment (SEA) at the planning and programme implementation levels.

Limited progress

While realising that informing on traditional risk assessment methods and their results is not sufficient for "public acceptance", the nuclear waste management community has entered a phase of looking for stakeholder participation input and for engaging social sciences in a much larger scale than was the case just ten years ago. Being still largely engineering enterprises, however, perhaps the nuclear waste management organisations were looking for engineering-like "solutions" in social sciences as a means to get acceptance. With only a few exceptions, however, the programmes are still struggling with frustration after considerable setbacks, especially in siting programmes. The key for success has not been found and there is a risk that frustration will increase even more to the level of stagnation of the nuclear waste management programmes in different countries.

A recipe for progress

Progress in OECD countries is thus quite limited in general terms. This is the case in Western Europe in spite of the fact that this is where most of the research has so far been done about transparency and participation. The new EU member countries are now developing their own approaches but they also want to gain from methodologies developed earlier within the EU research programmes. They especially want action based on fundamental principles rather than more theoretical research. In order to meet these demands but also to create new conditions for progress in all countries, we must demonstrate how participation and transparency link to the political and legal systems and how new approaches can be implemented in nuclear waste management programmes. This means for

1. There have been a number of efforts initiated by the European Union, the NEA and the international community at large: The COWAM I and II projects (2000-2006), the RISCOM II project (2000-2003) within the fifth and sixth framework programmes of the European Commission, the Forum on Stakeholder Confidence (FSC) by the OECD/NEA and the CARL project, are examples.

example that we need to know how the "transparency approach" and the "deliberative approach" can be combined and how they can be used to support the political system in which decisions, for example on the final disposal of nuclear waste, are ultimately taken.

Regulators' role

The regulatory bodies are key players in the radioactive waste management area and much is expected from them by the general public and by specific stakeholders such as potential host communities for final repositories. We have learnt that it is important to have independent regulators, with the capability of reviewing the safety assessment of the implementer, but experiences have also shown that there is a need to bring in the regulator early in participatory processes (e.g. for site selection) and to maintain this involvement. In Sweden, for example, communities want the authorities to be involved and they see the regulators as the people's experts. SKI and SSI have been involved from an early stage. They participate in EIA groups and play an active role in providing information on a community level.

Successful experiences in facility siting have shown that active regulatory involvement is needed, and also possible, without endangering the independence and integrity of regulatory authorities. The involvement of the regulators, however, must be made in a way that avoids possible bias by too close involvement. A borderline has to be established about the nature of their involvement to prevent inadequate consent to implementers' proposals before the formal licensing process begins. In general, a system with clearly defined roles of all actors, including NGOs, is to the benefit of transparency and awareness.

In radioactive waste management there are safety and radiation protection standards. It is equally important to communicate them and to make them transparent as the performance assessment (since one aim of performance assessment it is to show compliance with the standards). This is especially the case for guidelines about how the standards are to be applied. Here there is also more room for public input, for example on which are the relevant scenarios in performance assessment.

In summary, a regulatory body must be competent, willing to demonstrate its integrity towards the implementer and at the same time willing to take an active part in participative processes. Furthermore, as regulatory standards and criteria set the framework for performance assessment, it is important to let them also be the subject for public input.

Transparency and accountability

A regulator has the double role of being an expert and at the same time being an actor in the intermediate sector between civil society and political decision making, thereby mediating public values. This may explain why there are differences between national regulatory criteria. Even if the scientific basis is common, different countries, due to cultural differences, may have different views on value-laden issues such as long timescales, retrievability and human intrusion. Different regulatory standards may in fact reflect that regulatory bodies are responsive to citizen values.

The need for transparency in regulatory action thereby becomes especially critical. The citizens, but also the political decision makers, need to see both the factual and the value-laden components of regulatory guidelines and licensing decisions. In a democracy, transparency is a prerequisite for accountability. Only when both the political decision makers and the public have insight into the decision making basis can the citizens hold their elected representatives accountable. The question then arises of how regulators are accountable and to whom. As experts, grounding their regulations on science, they should follow rules of science. As mediators between politics and civil society they are ultimately responsible to the general public, getting their resources from the state budget.

There is a need for clarity about the double role of regulators, meaning that citizens should be given insight into how regulations, and their applications, relate to science and how they relate to public values. However, it seems like none of the models of participation that have emerged during latest decades have given us what we are looking for, namely a system providing society with awareness and accountability. Further work is thus needed to link them to the political and legal systems.

EXPECTATIONS FROM SOCIETY

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What is Society?

A former British Prime Minister claimed there was no such thing as society. In some ways, this is right for the notion of "society" is difficult to capture. As a category, society has many components covering, as it does, the relations, interactions, organisations, customs, classes and other groupings that make up communities. The idea of "community" is closely related and identifies those groups united by common interests or who inhabit a common territory. Both society and community are relevant to the management of radioactive waste. The values, norms and aspirations of a society profoundly affect the options we choose to manage wastes. And, since waste has to be managed in specific locations, the selection of a site will involve community aspirations as well as scientific criteria. Societal and community expectations are not set in aspic; they are dynamic, changing over time. Decisions taken in the present context have consequences stretching down the generations.

The time dimension makes us confront the problem of knowledge and uncertainty. It is present society that possesses the knowledge base which must be used to try to meet the needs and aspirations of the future. Yet, the future which does not yet exist cannot make its needs and aspirations known. Consequently, the idea of "expectations from society" tends to focus on the present rather than the future. It is possible to gain some understanding of what present day society thinks and feels about radioactive waste. This knowledge can be gleaned from opinion polls, surveys or from efforts at stakeholder and public engagement using deliberative processes of informed decision making, like, for example the methods undertaken by CoRWM in the United Kingdom. Such methods can also identify what present expectations of the future may be. What such methods cannot do is provide knowledge of future expectations and especially those of generations in the far future.

The expectations from society may be considered in terms of the relationship between society, knowledge and time. Four aspects may be identified. The first is the change in *social context* over time which defines contemporary expectations. The second is the contrasting *timescales* for considering future expectations. Third, there is the question of *timing* of decisions to meet expectations. And, finally, there are issues about the expectations of society in respect of the process of implementation. These aspects will be covered in the following sections followed by a conclusion drawing out the implications for the regulatory process.

The social context

The social context in which expectations are embedded may be visualised in terms of discourses changing over time. During the post-war period and up until the 1970s there was what might be described as a *Discourse of Technology*. This was a time of trust in scientists and confidence in nuclear energy with high expectations of the benefits from the peaceful atom. Nuclear energy was unchallenged and its development remained secretive. Radioactive waste was virtually a non-issue and it was dumped at sea or stored on land. By the 1970s societal support for nuclear energy was breaking down and a new *Discourse of Danger* was emerging. Accidents were either revealed (Windscale) or occurred (Three Mile Island and, much later, Chernobyl) which undermined public confidence and growing public concern was manifested in challenges to the nuclear industry and social conflict over nuclear waste. Radioactive waste management (RWM) became a social issue and, in many countries, technological solutions (disposal at sea, burying on land) were blocked. The problems of the rear end of the nuclear cycle became a significant reason for the decline of nuclear energy.

The focus on the problem of RWM and the search for new solutions led, during the 1990s, to a *Discourse of Consensus and Cooperation.* With the industry in retreat and a recognition that existing legacy wastes must be safely managed, hitherto opposing sides in the conflict warily joined in seeking solutions that would meet society's expectations for safety, security and participation in decision making. In several countries deep geological disposal was seen as the end point for RWM preceded by a period of long-term interim storage. Community participation in finding acceptable sites would be on the basis of a willingness to participate, a right to withdraw and a commitment to enhancement of their well-being.

It is evident that the solutions being pursued at any one time are contingent on the prevailing social context. Thus, at the present time and within the present scope of knowledge, deep geological disposal, possibly with some retrievability built in, is the favoured solution. But, it is also clear that, as in the past, the discourse might change and thereby shift the social parameters of decision making. There are some signs that this might be so. The renaissance of nuclear energy in the context of energy security and climate change may, in some countries, displace the fragile consensus if anti-nuclear movements suspect disposal is regarded as the solution for new build as well as legacy wastes. There is an ethical distinction between wastes that must be managed and those that could be managed. If the contemporary consensus breaks down then continuing storage may be the only acceptable means of RWM for the foreseeable future.

Timescales and expectations

Expectations may be visualised through different timescales. The distinction between *geo-scientific* and *socio-cultural* timescales has been discussed on a series of discussion papers and summaries emanating from the NEA Regulators' Forum (NEA, 2006a,b,c; 2007). Geo-scientific timescales are very long, measured in thousands and millions of years. Such timescales are the domain of scientists and regulators whose focus is on the long-term safety requirements of deep geological disposal. Hence they concentrate on such issues as geological stability, migration of radionuclides through the hydrosphere, on engineered barriers and packaging. Their primary concern is with how far into the future and at what level it is possible to predict the safety of a repository. As the time-scale extends into the future, so predictions shift from quantitative to qualitative until in the very far future it becomes impossible to make predictions with any expectation of fulfilment.

Socio-cultural timescales can be conceived as the time span which is of concern to us, the time during which our grandchildren will be alive. This is the period in which we have a stake and are concerned with future needs and expectations. By contrast with geo-scientific time, socio-cultural time is short, extending no more than one or two generations, a hundred years at most. In terms of RWM the focus here is on institutional control and on the need for flexibility in decision making enabling the future to have some stake in the decisions taken. Therefore, there may be some emphasis on interim storage and on retrievability as components of an end state of deep disposal. This is countered by the problem of increasing uncertainty about institutional control which places emphasis on early disposal.

Both timescales, though in different ways, raise the question of how far can or should our responsibility to the future extend? Answers are likely to differ. On the one hand, it may be argued that responsibility extends to the limit of the impact of our actions. There should be no cut-off point. This is morally absolute but it may be difficult to carry into effect. On the other hand, since we cannot know the consequences of our actions, a more pragmatic position recognises that the capacity to exercise responsibility diminishes over time. Whereas the absolute position places emphasis on the far future, the pragmatic position, acknowledging a cut-off point, is concerned more with the near term. These arguments are explored in more detail in CoRWM's Report on *Ethics and Decision Making for Radioactive Waste* (CoRWM, 2007a). From the regulators' perspective the implications of the consideration of different timescales is: what kind of standards can or should be applied and for how long? The discussion entertains the possibility that standards may diminish over time.

Timing: Societal concerns and decision making

The tension between socio-cultural and geo-scientific timescales is reflected in the issue of whether to deal with the problem of RWM now or delay it until later (CoRWM, 2006, Ch. 6). CoRWM identified a set of criteria which impinge on this question. They included: safety (protection from exposure); security (protection against removal of wastes); environment (minimise releases and impacts); socio-economic (creation of jobs, social well-being); amenity (visual, noise and transport); burden of future generations (reduce burden of exposure, effort, costs); implementability (of alternative options); flexibility (allowing for choice and response to change); and cost.

Clearly, safety and security are of paramount concern and are the central objectives of the regulatory process. These objectives support deep geological disposal as the best solution within the confines of present knowledge. But, on the issue of when disposal should take place, two other criteria are critical. They are burden and flexibility. A societal concern not to impose a burden on the future argues for dealing with the problem as soon as possible by early closure of a repository. This removes the need for continuing institutional control. It also focuses on near-term safety and security. While removal of burden tends to reinforce the case for early deep geological disposal, it takes a rather pragmatic approach to the far future. The approach can be justified on the scientific grounds that a safety case can be made that demonstrates geological disposal will not impose a burden on the far future. It may also rely on the pragmatic ethical argument that since containment cannot extend indefinitely there comes a point at which responsibility to the far future ceases.

The contrary option of deferring the decision to dispose of wastes is supported by the criterion of flexibility. If the societal expectation is that future generations should, so far as possible, have a say in decisions affecting them, then it is best to leave options open. This position is best served, at present, by the option of long-term interim storage (LTIS).

It is widely perceived that the conflicts between burden and flexibility criteria can be reconciled through the concept of phased geological disposal (PGD). This stretches the timescales for a period up to 300 years before repository closure thereby allowing more time for public confidence to develop. It may be said that PGD is the favoured RWM outcome of the contemporary discourse of consensus and cooperation.

However, it must be doubted that PGD is an effective compromise. It requires repository construction and emplacement of wastes. Retrieval, though possible, might be difficult and expensive. It is certainly a less flexible option than LTIS. Furthermore, it extends the period during which institutional controls would be needed and it imposes burdens of risk, effort and, potentially, cost, for a much longer time span than is the case with early disposal. In any case, it is recognised that early closure is unlikely to be achieved within a time span of a hundred years which may be said to provide sufficient flexibility and ensures that decisions to emplace wastes and to close a repository are, in effect, reserved to the next generations. From a regulatory viewpoint the emphasis may well shift from retrievability towards storage followed by early closure.

Society's expectations of the process of implementation

One of the characteristics of the contemporary discourse is the expectation that society, and more particularly local communities, will be able to participate in the implementation process. In the past, decision making was closed, secretive, centralised and technocratic and expressed in the approach of Decide Announce Defend. This approach has been almost universally supplanted by one characterised by an emphasis on societal acceptability and involvement based on deliberative forms of decision making. The broad expectations of society now comprise the following features: openness and transparency; a staged process of decision making; an expressed willingness of communities to participate as well as a right to withdraw from participation; the development of partnerships between local communities and implementing bodies; and the delivery of benefits designed to promote involvement and to sustain the well-being of communities.

This emphasis on community well-being is a key feature of contemporary expectations in the siting of repositories. It may be defined as, "those aspects of living which contribute to the community's sense of identity, development and positive self-image" (CoRWM, 2007b, p.12). Various ways of achieving well-being have been explored. For example, the German AkEnd committee placed an emphasis on regional potential and long-term development perspective. A repository "should have a positive effect on the region, but on no account must its influence be negative" (2002, p.180). The Belgian partnership approach stresses the necessity to integrate both the technical and social aspects of repository development. The Dessel partnership required a clear appreciation for their contribution to solving a serious societal problem. This appreciation implies tangible social, economic and cultural added value in the short, medium and long-term (emphasis in original, STOLA-Dessel, 2004, p.41). Similarly, the NEA Forum on Stakeholder Confidence devoted a workshop to identifying the potential value added by the development of a repository in a community. It argued that RWM projects "offer opportunities to improve well-being, consolidate knowledge, fulfil value ideals, elaborate community identity and image, and live out social relationships" (NEA, 2006d, p.7). In each of these approaches the idea of a positive improvement as a societal goal for future RWM projects is in striking contrast to the prevailing image of blight, disadvantage and environmental degradation. The expectation of community benefit has become a key element in the successful long term management of radioactive waste.

Implications for regulation

This paper has attempted to show that society's expectations of RWM are contingent upon the social context in which decisions are taken. Expectations are also influenced by the different timescales – socio-cultural and geo-scientific – over which the future is considered. It may be said that, within the present state of knowledge, deep geological disposal (DGD) has become the accepted approach to RWM, seemingly satisfying societal expectations for safety and security in both the near and longer term. Within this, phased geological disposal (PGD) has become the favoured approach, meeting both the need to avoid burdening the future while also providing flexibility for future generations to take decisions. However, it must be recognised that a new discourse could emerge and the social context and the state of knowledge could change, perhaps favouring other options such as LTIS, disposal in boreholes or some other approach to RWM. And, even within the DGD option the preference for early disposal rather than PGD might gain ground.

All these issues have implications for regulators. It is as well to recognise that regulation is not divorced from the social context. That is not to imply that regulators cannot exercise a disinterested and independent judgement. Indeed, one of the great strengths of the regulatory process has been the esteem and trust in which it is held in society. While regulators inevitably reflect the expectations of society, they also influence attitudes to safety and security over both the short and long term. The social role of regulation might be given more explicit recognition in three ways.

First, through greater regulatory involvement in policy making. In some countries, regulators have an input into the SEA/EIA processes. They are consulted over policy reviews and their role in monitoring, review and enforcement obviously has practical impacts on policy. In Sweden and Finland the regulators take a high public profile through communication and public meetings and have come to be regarded as the "People's Expert". There is an argument for regulator involvement in the process of repository design and development, a view expressed by CoRWM (2007b, p.54). This could increase public confidence in the process provided always that involvement in no way prejudices the regulators' independence in judging a safety case.

A second implication of the social role for regulators arises from the different time frames to be considered in RWM. There is considerable variation among countries on the question of how far into the future we should be concerned. The timescales appear to vary from 10 000 years up to a million years with some countries not applying a specific limit. The NEA has expressed a view that, 'while it may not be necessary or desirable to harmonise different regulatory criteria, it is important that we understand their origins and bases (NEA, 2006b, p.7). Therefore, it is necessary, "to achieve progress towards a common or consensus understanding of the objectives and issues related to long-term regulatory criteria for radioactive waste disposal" (*ibid*). As greater consensus on options and approaches to RWM emerges it will make sense to go further and harmonise criteria. RWM is more and more an international issue and radioactivity is transboundary which makes nationally based regulatory criteria increasingly difficult to justify.

Thirdly, there are the implications for regulators stemming from societal expectations changing over time. Regulation must meet a range of criteria affecting both the near term as well as the far future safety of RWM. The relative importance of criteria will vary leading, at different times, to an emphasis on this or that approach. Regulators must be aware of this and be open and transparent about the way criteria have been applied. Regulation as a practice has to integrate both scientific and social (including ethical) knowledge in developing the criteria on which safety cases are judged. Regulators perform an important role in helping to fulfil society's expectations of how radioactive wastes should be managed.

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EXPECTATIONS FROM EXPERTS IN ETHICS

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Introduction

In this lecture, I would like to make an ethical interpretation of the regulations issued by SSI (Swedish Radiation Protection Agency) and SKI (Swedish Nuclear Power Inspectorate). I am going to define the utilitarian core of the Swedish regulatory framework, but also identify a number of non-utilitarian elements, for example a number of principles of justice presented in KASAM's State-of-the-art Report from 2004. Thereby, I also hope to clarify possible spots of moral silence in the Swedish regulatory framework on nuclear waste.

Utilitarianism

There are many forms of teleological ethics, but the most influential is utilitarianism. The utilitarian principle was formulated in the following way by the English 18th century philosopher Jeremy Bentham:

> By the principle of utility is meant that principle which approves or disapproves of every action whatsoever, according to the tendency it appears to have to augment or diminish the happiness of the party whose interest is in question: or, what is the same thing in other words to promote or to oppose that happiness. I say of every action whatsoever, and therefore not only of every action of a private individual, but of every measure of government (from Bentham, *Principles of Morals and Legislation*, Chapter 1.)

Happiness is, according to Bentham, basically pleasure, positive experiences of satisfaction and joy. The opposite is suffering and pain. So an action is morally right if, better than any other action, it maximises pleasure and minimises pain – for all those affected by the action.

Deontologists such as Immanuel Kant or John Rawls disagree. Kant argues that it is wrong – and always wrong – to instrumentalise a person only as a means for certain ends. And Rawls argues that a good society is basically a just society.

Utilitarian and non-utilitarian elements in the Swedish regulatory framework

What kind of normative ethics is presupposed in the Swedish regulatory framework for nuclear waste management? I will divide the answer to this question in eight different points.

1. It is evident that some kind of utilitarian principle can be discerned in the regulatory framework: this can be formulated as a principle of negative utilitarianism (advocated, for example, by Karl Popper in his *The Open Society and its Enemies*, 1945). Negative utilitarianism (NU) requires us to realise the least amount of evil or harm. Commenting on

the 1§ in The Swedish Nuclear Power Inspectorate's *General Recommendations concerning the Application of the Regulations concerning Safety in connection with the Disposal of Nuclear Material and Nuclear Waste* (SKI, 2002), SKI states the following:

> According to 10 § of the Act (1984:3) on Nuclear Activities, the holder of a license to conduct nuclear activities is responsible for ensuring that the necessary measures are implemented to safely dispose of nuclear waste or nuclear material that are generated by operations and are not re-used. (SKI, 2002).

In other words: the ultimate goal of a nuclear waste depository is to prevent pain and suffering by the radioactive substances contained in the nuclear waste.

2. The principle of universalisability is generally regarded as an important part of utilitarianism and intuitively convincing. Nevertheless, it leads to a serious problem for classical utilitarianism, because it places intolerable burdens upon a given generation for the sake of futurity. We would be obliged to sacrifice almost everything we have, and save it for future generations. And our children, our grandchildren and so on, would similarly be obligated to save almost everything for the future. Arrow concludes that "the strong ethical requirement that all generations be treated alike, itself reasonable, contradicts a very strong intuition that is not morally acceptable to demand excessively high saving rates of any one generation, or even of every generation" (Arrow, 1995). Arrow arrives at an ethical position he calls *discounted utilitarianism*: each generation will maximise a weighted sum of its own utility and the sum of all future generations, with less weight on the latter. Really distant generations are all treated alike. In fact, discounted utilitarianism encompasses a deontological element, namely a principle of self-regard, of the individual as an end and not merely a means to the welfare of others.

3. The principle of self-regard favours the present at the expense of the future. But what are the consequences of this? At first, the principle of self-regard seems obvious and convincing. But on reflection, a certain need for qualifications arises. This has to do with a classical and often discussed argument against utilitarianism. Is it morally right to sacrifice certain persons or values for others? Isn't it worth the risk of harming some anonymous persons far off in the future? Given that the harm is small and/or that we have made the best we can to avoid it, isn't it a clear-cut case? The negative utilitarian might argue that future generations count and require consideration, but that the benefit the present generations can gain from nuclear power outweighs the risks (reduced by a depository fulfilling the criteria of BAT and optimisation) presented by nuclear waste to present and future generations. But how do we know that these risks are morally acceptable? This brings us to another amendment of negative utilitarianism. Besides the principle of self-regard, we need to take guidance from yet other deontological principles, namely, principles of justice and principles of responsibility.

4. SSI has in an appendix to their general guidelines to the regulation issued in 1998, attended to the problem about the amount of risk that is acceptable for future generations. According to the regulations, the risk for harmful effects for a representative individual in the group exposed to the greatest risk (the most exposed group) shall not exceed 10^{-6} per year (i.e. one in a million).

5. It seems that the ethical principle that best accords with such a statement is a principle of minimal justice, i.e. that every generation has a moral obligation to use natural resources (including uranium 236 in nuclear reactors) in such a way that we don't threaten the possibilities for life of any members of any future generations. In short: all human beings

have an equal right to life. Such a principle – and its application in SSI's regulations and guidelines – puts serious and rigorous constraints on the construction and maintenance of nuclear waste depositories.

6. Are we required to respect the freedom and autonomy of (members of) future generations? I think it is clear that we have such an obligation, which could be described as a weak principle of justice and that it has certain consequences for the way we construct the depositories for nuclear waste. If we are obliged to respect the freedom and autonomy of future generations, then we are also obliged (1) to build the depositories in such a way that these depositories do not put any burden on future generations in the form of control or maintenance of the depository; nor should we construct it in such a way that control and maintenance is impossible. Furthermore, (2) we are required to document the construction and content of the depository in such a way that future generations have sufficient information for any action they might want to undertake. Last, (3) these depositories have to be constructed in such a way that the radioactive waste is retrievable. We must not deprive future generations from their right to retrieve the nuclear waste – should they choose to do so.

One way to argue against taking any measures for the purpose of securing future generations´ right to control and/or retrieve – or not to control and retrieve – could be that such measures are detrimental to long-term safety of the repository. But I know of no scientific basis for this – nor for the opposite.

7. In KASAM's state of the art report Mikael Stenmark and myself argue that there is also a *strong* principle of justice which requires that we use natural resources in such a way that future generations can achieve a quality of life equal to the one we enjoy in the present generation. This makes an even stronger demand on the present generation than the other two principles of justice. It could – eventually – imply that we are required to transfer resources from our generation to future generations. But one obvious consequence not mentioned in the KASAM report 2004 could be that it is *the obligation that the present generations take care of the problem of designing, constructing and starting of a repository for nuclear waste in the first place*. I have not found this clearly stated in the regulations, but it is clearly recognised by the commercial enterprise that is responsible for the management of nuclear waste in Sweden.

8. There might be another argument for the principle of responsibility (i.e. that the present generations find a long term solution to the problem of nuclear waste). It could be termed the non-mañana-principle. Don't postpone until tomorrow what you can do today. Considering the resources and technology we have and the problem of leaving nuclear waste in unreliable interim storages around the world, the arguments against the responsibility principle – and ultimately the strong principle of justice – might be averted.

Conclusion

In sum, I took my departure in the principle of utility in the form of negative utilitarianism. Considering humanity as whole, we are required to realise the least amount of harm. Together with the principle of universalisability it takes us a long way through the Swedish regulatory framework. But there are important non-utilitarian elements in this framework as well. They could be summarised in terms of other principles, namely

1. The principle of self-regard (ultimately echoing the categorical imperative that an individual is to be used as an end and not merely as a means to the welfare of others), justifying the interests of the present generation;

2. The minimal principle of justice (which obliges us not to threaten any person's – present or future – possibilities of life) justifying the minimising not only of collective dose, but also of risks for (future) individuals;
3. The weak principle of justice (which obliges us to use our natural resources in such a way that future generations can satisfy their basic needs), justifying the KASAM principle that a repository for nuclear waste should be designed so that it makes controls, corrective measures and retrieval unnecessary and so that it does not make controls, corrective measures and retrieval impossible;
4. The strong principle of justice (which requires that we use natural resources in such a way that future generations might achieve a quality of life equal to our own) requires that the present generations – benefiting from nuclear power – also take care of the nuclear waste and not put such burdens on future generations that might diminish their achieving a quality of life equal to ours (= a principle of responsibility/producer pays principle), and also justifying;
5. The non-mañana principle, i.e. do not postpone until tomorrow what you can already do today.

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EXPECTATIONS FROM EXPERTS IN ETHICS

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The aim of this paper is to try to answer the three questions raised by Claudio Pescatore.

1. When the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management requires that we do not compromise the ability of future generations to meet their needs and aspirations, what is meant by "needs and aspirations"?
2. What are regulators expected to do to identify the needs and aspirations of the relevant future generations, and to provide convincing regulatory assurance that they will be protected?
3. How many generations ahead constitute "future generations" for the purpose of implementing sustainable development?

1. Why "aspirations" and "needs" are not good concepts

Even before answering these questions, I would like to say that in my opinion the concepts of "aspirations" and "needs" introduce more confusion than clarity into the discussions.

The concept of aspirations, it is true, is derived from a strong philosophical tradition that holds that the moral quality of acts is determined by their ultimate aim. According to this view, aspirations show me the nature of the "Good", and if I know what this is then I will be able to recognise what is correct and conducive to the Good. This type of ethics is described as "teleological" (*telos* = aim, purpose), and all the ethical systems inherited from antiquity, and from Aristotle in particular, are based on this kind of reasoning. These ethical systems are even described as being "conducive to happiness" or "eudemonic":

> "*All men want to be happy*. This sentence expresses the common conviction on which all ancient doctrines of right living are based, no matter how different they may be. All men want to live a successful life. A second line of argument takes this one step further, holding that this is the goal that makes men strive for everything else that they want. The third argument, which is eudemonic in the strict sense, holds that we ultimately judge whether human actions are right or wrong by whether or not they promote this goal."[1]

The main problem with this approach is that it assumes that all individuals aspire to the same good. While it is true that all men say that they aspire to happiness, they do not all define happiness in the same way. Already in antiquity a variety of antagonistic models proposed contrasting definitions, and the beginnings of modern thought emerged from the realisation that any attempt to build society on a hypothetical vision of the common good was not only impossible but often fatal. To return to our situation today, the concept of "aspirations" can refer to one of two things: firstly, it can mean that all

1. Robert Spaemann, *Glück und Wohlwollen. Versuch über Ethik* (Happiness and Benevolence), Stuttgart 1989.

individuals are in reality seeking the same "good" and that this is the process that must be protected, but in this case we must define what this good consists of, which is impossible in our pluralistic society; or, secondly, it can mean that each generation is entitled to define its own aspirations, which will always differ, but in this case we cannot protect anything since we do not know what these aspirations will be.

We seem to be on safer ground with the concept of "needs" and "essential needs". This concept stems directly from the definition of sustainable development given by the Bruntland Report (1987):

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs."

This is the definition that later inspired the rhetoric of sustainable development found, for example, in the Rio Summit's *Declaration on Environment and Development* (1992):[2]

> "The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations." (Principle 3)

However, a simple comparison of these two texts shows the vagueness that surrounds the concept of needs. Not only does this Declaration avoid defining what the needs of future generations will be, since this is impossible, but the emphasis is shifted imperceptibly from the "essential needs of the world's poor" (Bruntland), which focuses primarily on people, to the "needs of the majority of the people of the world" with "special priority" given to the "needs of developing countries" (Rio – Declaration, Principles 5 and 6). The Third Earth Summit held in 2002 in Johannesburg did not define what is meant by "needs" any more clearly. Its action plan, composed of 153 articles, covers a wide range of subjects such as poverty, consumption, natural resources, globalisation and respect for human rights, but it does not provide a basis for defining which needs should be taken into account in nuclear waste management.

What is more, we must wonder whether these general texts do not simply amount to the expression of desirable common social goals, but in terms that are incomparably less normative and binding than what would be required for the regulation of nuclear waste.

Can we find solid ground elsewhere for analysing the concept of "needs"? This seems problematic for one basic reason: what we mean by "needs" varies widely across time and place. For example, in the 18th century, Adam Smith had already pointed out that no-one in England could decently do without shoes, that in Scotland this applied to men only, and that many people in France felt no shame about wearing wooden clogs.[3] This relative aspect of needs is the reason why, in the general debate that long focused on the issue of essential needs, this approach has almost entirely been given up today.

The only more or less reliable approach to "needs" is the analysis made some fifty years ago by A.H. Maslow in his well-known pyramid. It distinguishes between five successive levels of needs that govern human behaviour; these are, starting from the bottom: (1) the physiological needs necessary for survival, such as food and shelter; (2) safety needs, such as protection from danger and from certain risks; (3) the need to belong, based on the social nature of human life: family ties, religious rituals,

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2. http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm
3. Adam Smith, *Wealth of Nations* V, ii, k, 3.

participation in civic life, a certain style of consumption to define one's social identity; (4) the need for esteem, in which gaining the recognition of others is a key factor, such as being admired for conspicuous consumption or being appreciated for altruistic behaviour, depending on the value system; and, lastly (5) the need for fulfilment in a very broad sense: leisure activities, sports, travel, education outside work, spiritual practices, etc.

It goes without saying that only a single type of specific need concerns us here, i.e. the safety of individuals from possible harm to their health caused by waste, but in this case it is better to say so more simply and explicitly.

2. Focusing on safety and fairness

Rather than speaking of "aspirations" and "needs", I propose that we focus on two more precise concepts, i.e. safety and fairness.

Before explaining what I mean by these concepts, I would like to point out briefly that nuclear waste management is a particularly complex issue because of the fact that it must be analysed in terms of two fundamentally different timescales:

- The short term, in which we make decisions about the future of our waste and in which we can be confident that our countries will be governed by democratic institutions.
- The long term, in which waste will remain highly dangerous to human life and the environment.

The geological timescale of nuclear waste is not the same as that of the democratic society in which we live. It is hard to predict how long our institutions may last. Making an estimate that is neither optimistic nor pessimistic, we can venture to hope that they will continue to survive for as long as they have already been in existence in some of our countries, i.e. for about two centuries. Beyond that, a solution must be found for a timescale of at least ten thousand years.

a) An ethical approach to the short timescale of democratic institutions

Pluralism

The OECD countries are all deeply pluralistic in terms of values, world views, etc. This being the case, no one can claim to have the last word on ethics by virtue of some privileged access to the truth. Unlike ethical systems based on the "good", democracy only presupposes very few values (essentially constitutions and human rights), leaving everything else to the judgement of individuals. For example, there is wide-ranging debate on the issue of nuclear waste. Let us consider here two extreme viewpoints on this subject. On the one hand, there are those who say that to respect the freedom of the men and women of tomorrow, waste must be sealed definitively today so that future generations will not have to worry about it. Others, however, argue that this approach would impose a tremendous risk on future generations by depriving them of any means of action.

A procedural approach to decision making

However, pluralism does not lead to relativism (all opinions are equal) or to subjectivism (everyone has his own truth), for our countries also have democratic traditions, with procedures that enable us to reach joint decisions about the meaning that we wish to give to our societies. On the basis of diverse concepts, the workings of democracy make it possible to reach a consensus about decisions that, although they may not always be good in the light of different conceptions of the Good, at least have the merit of being fair.

The role of an ethical audit

With this approach to ethics, which is more procedural and formal than substantive, the key is to define the conditions in which democracy can be exercised appropriately and to leave other matters to each generation so that they will be free to decide as they see fit on the issues that concern them.

Safety as the paramount value

The issue of nuclear waste – like other issues raised by the power that science and technology have given mankind – forces us to realise that these conditions go beyond the scope of human rights and the limited number of values formally embodied in countries' constitutions. As the philosopher Hans Jonas has pointed out, these issues require us to assume a new responsibility consistent with the magnitude of the threat to man and the environment that we are generating, which is no doubt unprecedented in history. In this case, being responsible involves a duty to act in a specific manner that Jonas expresses as follows:

> "Act in such a way that the effects of your action do not destroy the possibility of genuinely human life on earth" and, more positively: "Act in such a way that the effects of your action are compatible with such life continuing in the future."[4]

In Jonas' view, "genuinely human" life means life that preserves both the life of human beings and that of their environment. For Hans Jonas, as for most philosophers today, this responsibility cannot be ensured through the workings of democracy alone, since it is a precondition for the very possibility of exercising democracy.[5] This is no doubt the underlying idea that was awkwardly expressed with regard to needs, for even though democracies have made freedom the essential value that they wish to defend in addressing the challenges posed by certain issues such as nuclear waste, preserving the integrity of human life (health) must take precedence over freedom. It is in this sense that the requirement laid down by the Rio Declaration must be understood:

> States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem. (Principle 7)

This analysis has led the Swiss EKRA group[6] to make safety the most basic level of any ethical system that defines human life as the ultimate value. No other goal can be more important than this. For freedom to be defended there must first be human beings whose life, health and environment have not been harmed.

> "The paramount objective and value of every radioactive waste management concept has to be the safety of man and his environment. This fundamental principle is not in dispute. Safety is necessary for an individual to be able to act, make decisions and make use of his freedom."

Consequently, safety must not only be understood as the safety of the present generation, but also that of future generations for as long as radioactive emissions can be dangerous to human beings.

4. H. Jonas, Das Prinzip Verantwortung (The Imperative of Responsibility).
5. H. Jonas, "*Surcroît de responsabilité et perplexité ; entretien avec Hans Jonas*", *Esprit*, Nov. 1994, pp. 18-19.
6. Expertengruppe Entsorgungskonzepte für radioaktive Abfälle (EKRA), Disposal Concepts for Radioactive Waste – Final Report, Bern 2000.

It should be pointed out that, by affirming the central importance of safety, we are rejecting the attempt of some utilitarianists to introduce discounting[7] into cost-benefit analysis so as to take into account the remoteness in time of certain risks. Morally speaking, the importance attributed to events does not diminish the farther away they are in time, but remains fundamentally the same.[8] The reasoning by which, with a discount rate of 10% per year, the effects on people's well-being 20 years from now will only be one-tenth of the impact on people's well-being today, or that with a discount rate of 5%, in 400 years a million deaths will have the same value a single death next year, is not acceptable. The very principle of discounting must be rejected outright.

Fairness as the second-ranking value

The second key value, in our view, is fairness. Fairness is not on the same level as safety. It should only be introduced once safety appears to have been ensured in the light of our scientific and technological knowledge. Not only does it rank second on the scale of values, but it is being considered in lexicographical order. Just as we must look up a first word in the dictionary before looking up the second, we will only address the issue of fairness once safety has been guaranteed.

Fairness must be taken into account in the short timescale of democratic institutions because of the essential role it plays, without which democracy is impossible.

For example, nuclear waste management must place the smallest possible burden on future generations. This principle is justified not only by utilitarian arguments, but also by a consideration of fairness. There is an obvious asymmetry between the risk-cost-benefit ratio for our generation and for future generations. It would be unfair for the generations that benefit from nuclear energy to burden their descendants with its side effects and costs.

To give another example, in a democratic society we must defend the equal distribution of risks and, if this is impossible, provide compensation. What constitutes an acceptable risk is not determined solely on the basis of technology and the current state of knowledge, but is also dependent in large part on the consent of those concerned. Any level of safety is something that must be chosen. If compensation is to be given, this must be on the basis of individual consent and through negotiation and cannot be reduced simply to a process of mathematical modelling.[9] This has implications for nuclear waste management, which should allow subsequent generations – at least within the short timescale of democratic institutions – to take into account individual consent and negotiated compensation when there is unequal exposure to risks.

To give yet a further example, democracy can only be meaningful if citizens are free to give their opinion on the issues that concern them. It would be unfair for our generation to monopolise this freedom, leaving subsequent generations with the consequences of irreversible choices. For this reason, we must leave future generations with the possibility of choosing how this waste should be managed, in the light of technological innovations and risk levels chosen by society, etc. Future generations must be able to find storage areas, add to them and even retrieve waste in order to re-use it or neutralise it in a different manner. No method of processing radioactive waste is morally acceptable unless it allows each future generation of citizens the possibility of confirming or rejecting it through a

7. Discounting: the annual percentage used to weight a future value (cost or benefit) in order to determine its present value. A discount rate is thus the opposite of an interest rate, which is an annual percentage used to weight a present value in order to determine its future worth. In economics, interest is seen as positive and discounting as negative.
8. D. Parfit, 1983, pp. 31-37.
9. K. Shrader-Frechette, 199; D. MacLean, ed., 1986.

democratic decision, by virtue of their right to self-determination. This will have consequences in terms of the waste disposal model adopted as well as the funds allocated to waste recovery and the definition of new safety standards.

However, we also know that fairness is not only an essential element that makes democracy possible, but it is also an expression of democracy. Fairness is not something that is given once and for all, but it is something that is continually redefined. This is the case, for example, with the principle of equality. All citizens have equal rights and are guaranteed equal treatment and no one should be discriminated against because of their social situation, ideas or culture. However, some would like to extend this principle to all concerned, particularly when they form a circle broader than citizens alone. This is what is recommended by the proponents of communicative ethics (*Diskursethik*) following in the footsteps of Karl-Otto Apel and Jürgen Habermas. If we assume that the risks of radioactive waste have an impact that goes beyond the national level, would this not be the right approach? This intra-generational extension of fairness would also go hand in hand with an inter-generational extension. In the view of the EKRA group, the principle of taking everyone equally into account should be extended across time so that our descendants are placed in a position equal to ours. No one should be discriminated against simply because they belong to a different generation from our own.[10] Nevertheless, we realise that this extension of a basic principle of democracy may infringe the concrete rules of Swiss democracy today which, for instance, gives citizens of communes and cantons a right of veto over where waste may be stored.

Our societies, for example, give special attention to the most disadvantaged. However, what this means remains to a large extent open to interpretation. It can refer to the preferential option given to this group by the Bruntland Report, or to the Theory of Justice of John Rawls who has tried to explain the ethical intuitions of western democracies. For Rawls, fairness requires that any gains by the groups that are best off should go hand in hand with gains for those that are the worst off. This model might also be applicable to waste management. Although it is clear that we are better off because our generation has benefited from atomic energy, those who are worst off, i.e. who will no longer have access to this source of energy because resources have been depleted or who are endangered or harmed by waste, should be entitled to even more special consideration.

> To summarise: There must be intra- and inter-generational equivalence of opportunities and protection.

We have not yet mentioned the concept of social acceptance. This should be taken into account if possible, for example when a repository site is chosen by the local population, but in the view of the EKRA group, social acceptance is an ambiguous concept if it is not clearly seen as being secondary to fairness.

> Individual and social acceptance plays a third role because by favouring, within decision making, the present or the immediate following generations, it infringes to some extent the principle of fairness across generations.

b) An ethical approach to waste management over the long term

The timescales for radioactive waste management are so long, however, that they exceed the possibilities of our society in terms of passing on know-how and in terms of stability of political and social institutions.

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10. D. Parfit, 1983, pp. 31-37.

This being the case, the need to ensure passive safety – that is, independent of human activity – remains the essential requirement.

Fairness has not been forgotten, for the principle that assuring safety should constitute as small a burden as possible on future generations was adopted out of a concern for fairness.

> On the timescale of our civilisation, the requirements of safety in the interest of fairness mean that human intervention must be possible, at levels that remain to be defined.
>
> Beyond this timescale, the concept of safety being sought must be a definitive solution not requiring human activity in any form.

We can now try to answer the three questions raised by Claudio Pescatore:

1. Instead of the ambiguous concepts of "needs and aspirations", it would be preferable to speak of safety (rather than needs) and of fairness and social acceptance (rather than aspirations). These three concepts should be considered in lexicographical order, with the second only being considered after the first has been achieved. Fairness must only be considered once safety has been ensured and fairness should not be overlooked for the sake of social acceptance.

2. In the short timescale of democratic institutions, safety should not only take into account the state of our scientific and technological knowledge, but also the way in which our societies define acceptable risks and safely levels. The same is true of fairness, which cannot be defined absolutely, even though the principles on which it is based are clearly known: equality for all and reciprocity (what applies to one person must apply to another).

3. In the long-term timescale that exceeds the life expectancy of our democratic institutions – two centuries? – safety is the only factor that must be ensured in an entirely passive way on the basis of our scientific and technological knowledge. It must be possible to shift at any time from an approach to safety based on human intervention to an approach that is totally independent of any human intervention, without having to marshal any special technological or financial resources.

EXPECTATIONS FROM ETHICS

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Introduction

Let me begin with a note of gratitude, not only for inviting me to participate in your conversation about an extremely significant matter, but for raising the ethical questions in the first place. I have great respect for the European Community and the leadership they have taken in doing so. In particular, persons like Claudio Pescatore, Kjell Andersson and Charles McCombie have taken on this task far before it was popular to do so. Societal concerns about acceptance of nuclear waste disposal have not been confused with ethical demands to do the right thing when it comes to our obligations, even though these two areas come together in the political arena.

This workshop concerns the challenges in regulating for the long-term safety of radioactive waste. As one of the "ethics experts" invited to the workshop, I was asked to comment on ethical expectations in regulating safety for future generations. The challenge is to find a just solution-one that provides for a defensible approach to intergenerational equity. Equity is not about equality, i.e. treating all generations alike. Rather, it concerns treating like cases alike; when dissimilarities occur among generations, the question arises as to whether those differences are morally relevant ones, i.e. ones that permit us to treat generations differently and to still meet the demands of justice. And, the question must be asked, "In what ways do they make a moral difference?"

This session of the workshop examines whether or not multilevel standards for the disposal of nuclear wastes are just, or are morally permissible. Some countries have proposed different standards for different time periods, either implicitly or explicitly. In doing so, have we preserved our standards of justice or, instead, have we abandoned it?

In earlier periods in which standards were being set by various countries, the answer seemed quite simple. One standard, spanning the entire period of health risk from exposure to radionuclides from a geological repository, was proposed. The ethical principle which supported a single standard was cited throughout the nuclear community in the following way: "Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today."

What has happened since these earlier days? Why are we rethinking this view?

In sorting through these issues, I would like to raise six important points. In doing so, I will be supporting the nuclear waste community's initial moral intuition that by and large justice toward all generations can best be met by a single standard. However, I will be making some finer points along the way in order for us to understand what it means to require a single standard.

Point 1:

Ethicists disagree about whether we have duties to future generations on *the very grounds* that are now being used by the nuclear waste community to create multi level standards across the time span of many generations. When the nuclear waste community claimed over 10 years ago that we had obligations to future generations, I do not believe it understood the full import of that claim. For decades ethicists have been arguing about this very issue. There is a large and significant body of thought (writing) that does not support these obligations.

Here is how the argument against such duties goes: Future generations are not yet living; they do not exist. Specific persons may never come into existence since our present actions affect the future. We do not know what they will be like if they do. The non-existence of future humans, which specific humans will exist, their DNA structure, and their abilities to withstand disease, affect any obligations to future persons. They, in fact, establish that future persons have NO moral worth. Hence, our duties to present humans *always and in every case* trump any duty *we think* we might have to future generations. These time-dependent features of future persons do not merely weaken any belief we have in obligations, they erase them.

Whether you agree with this or not, it is important to point out that the very reasons given by ethicists against the belief of duties to future generations are those that are now being summoned to question whether we should have a single standard spanning all generations. Philosophers have argued that our ignorance of future, compounded by its uncertainty, and our inability to have predictable effects in the future are sufficient grounds for denying that we have obligations to future generations. These grounds are not used to create a gradation of the strength of our duties; rather they are used to deny those duties altogether. The nuclear waste community originally swept aside these considerations, but now it is experiencing a felt need to return to them as it faces the daunting task of meeting regulations created decades ago for the long term.

Here's the problem: it is morally problematic to "have one's cake and eat it too." If we do have duties to the future, then we can't turn to the very arguments used to deny these duties, in order to weaken them. In fact, ignorance or uncertainty in the moral life functions more often than not to generate conservatism and strengthen duties. Our moral intuitions seem to say, if you aren't certain about the future or the past, then act more cautiously and provide stronger standards, regulations, processes, etc. than weaker ones.

Point 2:

Ethicists have established reasoned claims that we have duties to future generations. But, they do not develop a *gradation* in the strength of that duty. The arguments advanced by ethicists who deny duties to future generations have been vetted among philosophers at great length. While they may not have convinced all those who oppose such duties, there have been persons who have mounted effective counter-arguments against these views. So, the nuclear waste community is not alone in thinking that we have obligations to future generations. However, there is little belief that those obligations differ in strength merely because of the time in which the moral agent or moral patient is located. The standards that are set for the present generation are generally regarded as those which should also be set for near and far future generations. This is because time (and with it, ignorance and uncertainty) are insufficient grounds on which to say that our duties may be weakened. To use an analogy, persons are born with various pigmentation in their skin, but we do not use the shades of the human skin to determine the strength of our duties to these persons. Lighter shaded people don't earn a stronger moral debt from us than do persons with darker shades of skin (or vice-versa). Were we to do so, we would think of ourselves as discriminatory.

John Rawls, in his well-regarded *Theory of Justice* states: "Now the contract doctrine looks at the problem from the standpoint of the original position. The parties do not know to which generation they belong or, what comes to the same thing, the stage of civilisation of their society. They have no way of telling whether it is a poor or relatively wealthy, largely agricultural or already industrialised, and so on. The veil of ignorance is complete in these respects." (Rawls, 1971). No future generation is more important than another as justice has no time preference. "The life of a people is conceived as a scheme of co-operation spread out in historical time. It is to be governed by the same conception of justice that regulates the cooperation of contemporaries. No generation has stronger claims than any other" (Rawls, 1971). Each generation is obligated to save for the next (in terms of welfare) and each generation is obligated to maintain the same democratic institutions over time. Rawls points out, "We can now see that persons in different generations have duties and obligations to one another just as contemporaries do. The present generation cannot do as it pleases but is bound by the principles that would be chosen in the original position to define justice between persons at different moments of time. In addition, men have a natural duty to uphold and to further just institutions and for this the improvement of civilisation up to a certain level is required. The original position is so defined that it leads to the correct principle in this respect. In the case of society, pure time preference is unjust: it means (in the more common instance when the future is discounted) that the living take advantage of their position in time to favour their own interests." (Rawls, 1971)

I do not believe that the present day nuclear waste community desires to take advantage of their position in time of living in the present to favour their own interests. Such opportunism is not morally praise worthy.

Point 3:

The recent surge in interest in sustainability appears to provide a moral defense of multi level standards of safety; the use of a continuum of static, strong, weak and minimal principles of justice is used to establish that our duties differ over different time spans. But, use of sustainability ethics does not support the creation of different safety standards. This is partly because the main issue regarding nuclear waste disposal is safety. Even the weakest principle of justice supports no difference in standards of safety between present, near, and far future generations. Sustainability ethics supports differences among welfare interests once basic safety needs are met.

The additional challenging in using a sustainability ethic is that the case for sustainability has not been sufficiently made. It may never be made by certain countries because it requires broadening the moral horizon to include arguments in support of nuclear power. Some countries do not wish to expand the use of nuclear power; they see no need for a reliance on such an energy source. The sustainability argument is more robust and requires a connection back from waste to nuclear energy production. This very point is made in Annex 7 document provided for this workshop when the authors point out:

> However, the discussion with respect to long-lived radioactive waste differs from typical sustainable development discussions in two important respects. The first is that in many countries, decisions on the course of action to deal with long-lived radioactive waste are separated from decisions on development of nuclear energy, and even where they are not, the current discussions on radioactive waste are taking place well after the decision to proceed with the development that created that waste. Regardless of the outcome of decisions on future development of nuclear energy, there is an obligation to deal with existing wastes. Nevertheless, when the context of the discussion does not include development, a significant aspect of the sustainable development paradigm is missing, and we can expect that there may be difficulties in applying the full paradigm (41).

Point 4:

What might allow for multi-levels of standards of safety whereby standards for the future are lowered in favour of resolution of a problem in the present is the moral trumping of needs over interests.

Basic needs concern human survival (life) and health. Welfare interests are associated with the quality of life. Much of the concerns taken up in environmental ethics about intergenerational equity are related to welfare interests or aspirations, i.e. in ensuring a biodiverse world, in protecting environmental resources from depletion so that they may also be used by future persons, in degrees of robust sustainability, etc. This is why the evolution in thinking in the received, peer-reviewed scholarship has turned to the provision of future opportunities and compensation for the *loss of opportunities* rather than *the provision of specific resources*. (DesJardins, 2006) The emphasis on sustainability of resource utilisation and trusteeship of the environment represents these concerns.

But, for the issue at hand, regulations are focused on basic needs-preservation of life and protection of human health. It is sometimes the case that a present basic need will conflict with a future welfare interest. There is some agreement that basic needs of persons in the present trump future welfare interests if there are no alternative ways in which the basic need can be met. This fact of ensuring that no alternatives are available is another moral trumping card even when basic needs in the present and the future are in conflict.

In applying this carefully to the issue at hand, the ethicist would want to know if the conflict is between 1) a present basic human need and a future human need; if so, this presents us with a moral dilemma, a truly thorny and complex ethical situation to confront, 2) a present welfare interest (often termed "want or aspiration") and a future basic human need, 3) a present basic human need and a future welfare interest, or 4) a present welfare interest and a future welfare interest. The nature of the interest will determine how best to resolve the conflict. A determination must be made about the viability of alternative courses of action.

The grid below displays this conflict-resolution scheme:

Grid 1

Present persons have:	Future generations have:	Resolution
Present basic human need. (need).	Future basic human need. (need).	A moral dilemma which needs dissolution; dilemmas are, in principle, irresolvable.
Present welfare interest (want).	Future basic human need. (need).	Future trumps present.
Present basic human need. (need).	Future welfare interest (want).	Present trumps future.
Present welfare interest (want).	Future welfare interest (want).	Present may trump future in some hierarchy of wants.

In using Grid 1**,** a regulator must show that there are only welfare interests at stake to the future generations and that future generations' basic needs are not threatened; at the same time, they must show that basic human needs are at stake for present persons. However, if basic human needs are also at stake for future generations, we have a moral dilemma. A moral dilemma presents us with an apparent conflict between our moral duties, whereby following one transgresses on the other. A common way of handling a moral dilemma is to show that it doesn't really exist by dissolving one of the "horns of the dilemma." This is how some ethicists would handle the problem at hand, i.e. by denying that we have moral duties to future generations or by pointing out that perceived needs are really only wants. Another approach is to show that a proposed resolution, although not ideal is the greater of two goods or the lesser of two evils. In this instance, assuming the present basic need for life and health conflicts with the far future basic need for the same, minimally, the regulator must clearly demonstrate that there is no feasible alternative to geological disposal and there is pressing need for nuclear energy production (rather than an alternative) in order to override the basic needs of future generations to meet the basic needs of persons living in the present. Some countries may, indeed, be able to make this argument successfully.

Finally, if only welfare interests are at stake for present persons, i.e. their life and health is not threatened but their interest in providing renewed energy resources is in jeopardy, the regulator would need to demonstrate that no life or health of far future generations are threatened. Grid 2 below represents the application of Grid 1 above:

Grid 2

Present persons have:	Future generations have:	Resolution
Basic human need to ensure equal protection of life and health from radiation exposure from high level nuclear waste at reactor and other sites.	Basic human need to ensure equal protection of life and health from radiation exposure from breached nuclear repository.	If there is no viable alternative repository sites and fuel sources (if it cannot provide protection for both present and future generations), we have some hard choices to make for which there are no easy "principled" or "trumping" resolutions.
A welfare interest in promoting nuclear energy as a viable energy source for present persons.	Basic human need to ensure equal protection of life and health from radiation exposure from breached nuclear repository.	A multiple standard for the far-future generation **is not morally permissible**. Current welfare interests do not trump future basic needs.
Basic human need to ensure equal protection of life and health from radiation exposure from high level nuclear waste at reactor and other sites.	A welfare interest only in promoting optimisation of energy resources.	A multiple standard that weakens the standard for the far-future generation **is permissible**.
A welfare interest in promoting nuclear energy as a viable energy source for present persons.	A welfare interest only, in promoting optimisation of energy resources in the future.	Present may trump future.

Point 5:

Assuming there is no moral trumping of present needs over future aspirations or interest, then a single safety standard should apply across present, near and far future generations. What standard should this be? Is this a wholly arbitrary decision?

Relevant considerations here include current regulations in other areas, natural background, and international agreement as a basis for this standard. The difficult argument to make is to use natural background as a standard, without committing the "naturalistic fallacy."

Point 6: (the most complex point to be made)

A distinction between *capacity to assume or perform a duty* and *the strength of the duty itself* must be made. The strength of duty itself remains the same, but the capacity to fulfil the duty

may justify the shifting of the duty, in this case, from present generations to future generations if capacity increases by virtue of certain uncertainties decreasing with time. The authors of the KASAM 1998 report may, in fact, be correct in claiming that "increasing uncertainties means that our capacity to assume responsibilities changes with time." (KASAM, 1998) **However, a reduced capacity does not lead to the conclusion that "our moral responsibility diminishes on a sliding scale over the course of time." (ibid.)**

Uncertainties in repository performance are relevant to the question: *Who* has these responsibilities to future generations if current persons lack capacity? In other words, if uncertainties over time affect our *capacity* to ensure that an equivalent level of protection is provided by a repository at a given site, and we have no alternative but this site (e.g. no other rock body can give us the assurances we need for the entire period from post-closure to peak dose period), then how can this responsibility to future generations be met?

Our *capacity* to assume those duties may, indeed, differ over time. Near and far future generations may be able to perform the duties better than we can in the present. They may have new technologies, reduced uncertainties, and expanded knowledge that time affords. Hence they may be able to do a better job of protecting human health in the future. The concept of the "rolling present" represents the fact that we transfer our duties over time; it does not represent the fact that we reduce them or weaken them because of uncertainty associated with time.

The concept of the "rolling present" emerged in the nuclear waste community as they were dealing with concerns that permanent disposal of nuclear waste did not leave open the ability to act on the solutions that the future might hold. If we cannot construct repositories now that will provide the same standard of protection to future generations as we provide present persons, then the rolling present allows us to transfer duties, along with resources and knowledge, without disenabling present persons or harming future generations.

A similar concept was introduced by John Rawls in order to help understand that our duties to future generations will need continuity over time. Others have introduced this concept of ensuring continuity in fulfilling our obligations, including the work cited in the KASAM report by Lars Ingelstram which calls for *an institutional constancy*. (KASAM, 1998) KASAM states, "The question, Ingelstram argues, then becomes one of whether or not it is possible to bridge the time interval, or discover a link between the present and the future so that the comprehensibility and credibility can be preserved even for complex socio-technical systems designed to function for an extended period of time where we have no possibility to demonstrate that they will function as planned on the basis of the demands we make for long-term safety. Ingelstram claims that this link is *institutional constancy* by which he means the necessity to build in control mechanisms in society's institutions to continuously test to see if promised results are achieved."

KASAM points out that geologic disposal has been thought to provide the stability needed to protect human health from radiation exposure due to a repository breach. Not too long ago the nuclear waste community found this appeal to obligations to future generations both morally praiseworthy and politically effective. However, as we come closer to realising the complexities and uncertainties associated with repository performance, unless alternative sites and alternative engineering is available to restore such stability, we have shifted to a concept of "the rolling present" that is thought to displace some of our obligations onto the future. As I have pointed out under point 4 above, the EPA is not empowered to respond to the demands for institutional constancy required by a rolling present.

In an earlier report by the Alternative Group in Sweden, this idea of a rolling present surfaced but it was coupled with a warning that this would require a new way of approaching the regulatory requirements for nuclear waste disposal. In this same publication, the question of how long the present rolls is raised. The response points out that it is a phenomenon which, in practice, began when the first reactor was created and ends when an irrevocable decision is made, most likely when the repository closes and the waste becomes difficult to retrieve. Swedish citizens are asked to contemplate "which decisions can with a rolling present be left to future generations and which decisions are they qualified to make in the near future." (Nilsson, 2001) This demonstrates the lack of fit of this concept for the EPA's task at hand. The EPA is not authorised to delay the decision on protection standards and the multiple dose standard they propose does not reflect the need for a rolling present.

To be clear, were a shift in the locus of moral responsibility needed, it does not change the strength of the moral duty we have to provide equal protection to individuals from harm (no matter how "negligible") to their basic need for health. As Richard Howarth points out in his article "Intergenerational Justice and the Chain of Obligation," the links made among succeeding generations are equally strong. Our link to the children of today, a presently living but nevertheless different generation than our own, is just as strong as the subsequent links made between our children and theirs, and their children's children and the children of these children's children and so forth. The strength of the link doesn't weaken merely because they live later in time from us. They bear the same strength in the link between the succeeding generation and theirs. Our place in the chain doesn't weaken their link (i.e. their duties).

If we believe *our* children should be exposed to no more that x (15 mrems/a), there is no reason for us to think and act in such a way that our distantly-related generations should not also be exposed to no more than x (15 mrems/a). Why would the child who lives on 1 January 10001 be entitled to less protection than our children today? What we believe to be just in our relations to our contemporaries should be extended to define standards of just distribution between generations. "To the extent that principles of justice require equal treatment for contemporaries, they require equal treatment for future generations as well." (Howarth, p. 135) The chain of obligations does not weaken our duties to future generations; it does just the opposite: it establishes those duties as equally strong across generations.

Understanding this comes from untangling the distinction between our **capacity to fully assume our duties** and **the strength of the duties themselves**. These two aspects of the moral life must not be confused with each other.

Summary

The six points below provide us with some moral maps we might use to negotiate our way to a just solution to the disposal of nuclear waste.

Point 1:

Ethicists disagree about whether we have duties to future generations on the very grounds that are now being used by the nuclear waste community to create multi-level standards across the time span of many generations. We must be careful to not to "want our cake and eat it too."

Point 2:

Ethicists have established reasoned claims that we have duties to future generations. But, they do not develop a *gradation* in the strength of that duty.

Point 3:

The recent surge in interest in sustainability appears to provide a moral defense of multi-level standards of safety; the use of a continuum of static, strong, weak and minimal principles of justice is used to establish that our duties differ over different time spans. But, use of sustainability ethics does not support the creation of different safety standards.

Point 4:

What might allow for multi-levels of standards of safety whereby standards for the future are lowered in favour of resolution of a problem in the present is moral trumping of needs over interests.

Point 5:

Assuming there is no moral trumping of present needs over future aspirations or interest, then a single safety standard should apply across present, near and far future generations. What standard should this be? Is this a wholly arbitrary decision?

Point 6: (the most complex point to be made)

A distinction between capacity to assume or perform a duty and the strength of the duty itself must be made. The strength of duty itself remains the same, but the capacity to fulfil the duty may justify the shifting of the duty, in this case, from present generations to future generations if capacity increases by virtue of certain uncertainties decreasing with time.

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EVOLVING EXPECTATIONS FROM INTERNATIONAL ORGANISATIONS

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1. Introduction

Implementation of the geological disposal requires a strategy that provides national decision makers with sufficient confidence in the level of long-term safety and protection ultimately achieved. Traditionally, protection from harm has been interpreted solely in the context of radiological protection, i.e. in term of dose and risk to human health. However, for many people, the concept of protection from harm has a broader meaning, including the protection of the environment, ethical concerns and socio-economical interests of communities. Consequently, the process of technical or safety regulation is embedded in a large societal decision making process.

A number of countries have already established regulatory criteria, and others are now discussing what constitutes a proper regulatory test and a suitable time frame for judging the safety of long-term disposal. Regulators must nevertheless make decisions with consequences reaching far in the future based on the information presently available. Therefore each regulatory programme seeks to define reasonable tests of repository performance, using protection criteria and safety approaches consistent with the culture, values and expectations of the citizens of the country concerned.

There are differences in how protection and safety are addressed in national approaches to regulation. Numerical long-term protection criteria and the methods of demonstrating compliance differ from country to country and the bases for setting the criteria appear also to vary. However, as it was recognised in the 1997 NEA Córdoba workshop *Regulating the Long-term Safety of Radioactive Waste Disposal* [9], what is of key importance is to reach a level of consistency at the level of the overall safety objectives and to be able to explain the differences.

The LTSC group's investigations have identified a number of important contributing factors to national differences, among them: the complexity and non-uniformity of the regulatory decision-making process across nations, a lack of established consensus on how to characterise and measure protection in the distant future, not having fully worked out the fundamental ethical issues related to the nature of current society's obligations to the future. Reflecting these national differences and the factors influencing them, international guidance has also been evolving with time and is still in the process of evolution, e.g. the recent developments in ICRP guidance (see below).

This paper presents a general overview of the evolution of international guidance and positions issued by international organisations (ICRP, IAEA, NEA) during the last decades, in particular since the 1997 NEA Córdoba workshop. Positions taken by other international and national and institutions and organisation are also considered.

2. Overview of the development of international guidance

Recommendations on general radiological protection and safety objectives for practices implying a radiological risk and, specifically, for activities related to long-term radioactive waste management and disposal, have long been made by international organisations, in particular during the last 30 years. In a broad sense, it may be considered that international guidance includes:

- Policies approaches, objectives, requirements, etc. contained in international Conventions, legally binding for countries which have ratified them, or European Council Directives in case of European Countries;
- Principles, objectives, recommendations, requirements and criteria issued by international organisations, specifically the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA), according to their respective statutes;
- Positions and approaches of the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), expressed through collective opinions, policy papers, and reports issued with a high level of consensus.

A general overview of the international safety and radiological guidance developments since 1985, is listed in chronological order in Table 1, showing separately those developments published since the NEA 1997 Córdoba workshop.

Table 1. **Chronologic development of international guidance and positions concerning the long-term aspects of radioactive waste management and disposal**

Date	ICRP	IAEA	NEA
1985	ICRP 46 Principles for radioactive waste disposal [1]		
1989		SS–99 Safety principles and technical criteria [2]	
1991	ICRP 60 Radiation protection recommendations [4]		Collective Opinion on safety assessment [3]
1995		SF–Principles of radioactive waste management 111-F [5]	Environmental and ethical basis: Collective Opinion [6]
1997	ICRP 77 Radiation protection policy for disposal [7]	Joint Convention [8]	Regulating the long term of radioactive waste disposal [9]
1999			Confidence in the long-term safety [10]
2000	ICRP 81 Radiation protection as applied to disposal [11] ICRP 82 Prolonged radiation exposure [12]		
2003			The regulator's evolving role [13]
2004			Post-closure safety case [14] Stepwise Approach to Decision Making [15] The handling of timescales [16]
2005			The regulatory function [17]
2006	New Recommendations on Radiological Protection [20]	WS-R-4-Geological disposal [18] SF-1 Fundamental safety principles [19]	NEA long-term safety criteria initiative discussion document [21]

In parallel, *environmental* and *social values* have been receiving more attention and are currently acquiring a similar importance as the technical aspects in the decision-making processes, having been reflected in some of the successive international developments mentioned above, e.g. references [9], [11, 13, 15 and 20], form the essence of the Aarhus Convention [22] and the European legislation on environmental impact assessment of certain projects and plans (EIA) [23-24] and SEA [25].

Moreover, the *ethical dimension* deeply associated with the long-term safety and the protection of future generation has been the focus not only of guidance by international organisations, e.g. previous references [5-6, 8, 11, 18-21], but also of recognised independent National Advisory Bodies with direct influence at national level, as well as at international level. These institutions have promoted new perspectives, combining gradual and practical approaches to which considerations may be useful for a better understanding of our obligations to future generations, NAPA [26], EKRA [27] and KASAM [28] (see the Annex to this paper).

Evolution of these guidelines over time demonstrate an evolving understanding of the long-term implications, as may be deduced from the remainder of this paper.

3. Evolution of ICRP recommendations

The ICRP system of radiological protection has significantly evolved through periodic publications of general recommendations which historically have been followed by additional recommendations addressing specific issues. Thus, the radiological protection system developed over some 30 years was set out in Publication 60 [4], which is currently under revision and which will be superseded by a new ICRP publication planned to be issued in 2007 [20]. Specific ICRP recommendations for radioactive waste management and disposal provide a framework for the consideration of the related long-term safety and radiological protection aspects. This framework has been progressively completed and evolved over time as shown in Table 2.

Table 2. **Overview of the evolution of some ICRP concepts and approaches**

ICRP 46 1995	**ICRP 77 1997**	**ICRP 81 1998**
Normal/probabilistic situations Dose/risk limits (1mSv/year – 10E-5 respectively) Dose/ risk upper bounds: a fraction for each source *Optimisation of Protection*: Similar to ALARA, Application to comparison of options.	*Doses and risk constraints:* 0,3 m Sv/yr and 10E-5 respectively. *Potential exposure*: is exposure that is not certain to occur, but to which a probability of occurrence can be assigned. Recognition of difficulties in applying the radiation protection system. *Optimisation of protection*: broad interpretation of doing all reasonable to reduce dose. Recognition of the judgmental nature of this principle. Mention of the term *best available techniques (BAT) or best available technology not entailing excessive cost (BATNEEC).* *Protection of future generation*: there are also *ethical questions* in judging the importance of the possible harm.	*Dose and risk constraints* values to be applied remain the same. *Natural processes* – two approaches: aggregation of risk, combining doses and probabilities, and disaggregated dose/probabilities. *Human intrusion scenarios*: risk-based approach – *reasonable effort* to reduce probability – use of stylised scenarios (dose of 10mSv/y as generic reference level). *Constrained optimisation*: this is the main approach to evaluating radiological acceptability of a disposal and should be conducted in a structured, essentially qualitative, way. Application of *technical and managerial principles* during the disposal system development are recommended to *enhance the confidence,* such as*: defence in depth, sound engineering principles and practices, a comprehensive quality assurance, iterative safety assessment.*

Besides a gradual evolution of the numerical dose and risk limits and constraints values, the publication of successive ICRP guidelines shows an evolving understanding of long-term implications and a recognition of the complexity of the application of the radiologically-based protection system to the long-term aspects of the radioactive waste disposal. In addition to the evolution of previously defined concepts, new concepts have emerged such as "*constrained optimisation" BAT (best available techniques)* and the more focused application of best practice in terms of *technical and managerial principles,* all of which are associated with the optimisation of protection and the iterative disposal development process. These developments have provided greater flexibility in terms of the possible routes to ensuring compliance with the fundamental objective and criteria.

3.1 Focus on the ICRP 81 and the last general ICRP recommendations

In terms of the evolution of the ICRP recommendations, ICRP 81 presents a broader perspective on the meaning of the dose and risk values and on the assessment of compliance of radioactive waste disposal over very long time frames, in terms of moving beyond a purely radiological protection focus to inclusion other social, economical and ethical considerations. The new ICRP recommendations (draft 2006), which make reference to ICRP 81, reiterate previously stated positions regarding the meaning of dose and risk in the far future; the application of the optimisation and of dose constraints; and take into account the nature of the decision-making processes, on the grounds that the involvement of all concerned parties is needed to achieve more flexible and sustainable decisions. Some of the statements and positions from the new recommendations are shown in Box 1 below.

Box 1. **Some of the ICRP 81 and new ICRP general statements and positions**

ICRP 81

- *Dose and ris*k as measures of health detriment can not be forecast with any certainty for periods beyond around several hundred years into the future. Rather, both should be increasingly considered as *reference values* for the time periods farther into the future.
- Assessment of compliance should be based on a comprehensive *safety case*, supported by *multiple lines of reasoning*.
- Consideration of two approaches to evaluate the performance of geological disposal over long timescales: use of *quantitative estimates* of dose and risk on the order of 1 000 to 10 000 and use of *qualitative calculations* further in the future making use of stylised approaches.
- *Regulatory policies* and *decision making* are not solely based on technical matters. They take into account expectations of civil society, international experience, ethical considerations and practical needs of implementers.

ICRP recommendations (draft 2006)

- In case of exposure taking place in the future, additional uncertainties are involved. Thus dose estimates should not be regarded as measures of health detriment beyond times around several hundreds of years into the future. Rather, they represent indicators of the protection afforded by the disposal system;
- *The optimisation of protection* is a forward-looking *iterative process* aimed at predicting exposures before they occur, taking into account socio-economic developments and requiring both quantitative and qualitative judgments.
- *The way the principle of optimisation should be implemented is now viewed as a broader process reflecting the increasing role of individual equity, safety culture and stakeholder involvement.*
- *Decision making* processes may depend on other *societal concerns*, considering that involving all concerned parties in the process reinforces the *safety culture* and *introduces the necessary flexibility in the management of radiological risk that is needed to achieve more flexible and sustainable decisions.*

4. Evolution of IAEA recommendations

A majority of the safety and radiological protection principles and criteria contained in the IAEA's general and specific safety standards have been derived from the recommendations of the ICRP and consequently evolve in the same direction, as may be observed in Table 3.

The responsibility of current generations for the protection of future generations has been always considered as a fundamental objective of radioactive waste management and disposal throughout the different IAEA recommendations since 1989. This objective, as stated in the principles of the specific Safety Fundamental 111-F, is also one of the objectives of the Joint Convention and is reported in the recent IAEA Safety Standard WS-R-4[1] (Geological Disposal of Radioactive Waste Safety Requirements). It may be observed that although the responsibility to, and protection of, future generations are restated as being the fundamental and crucial objectives of radioactive waste disposal, the terms in which the objective is expressed show a shift towards taking into account social and environmental considerations and the inherent difficulty of demonstrating that this objective will be discharged in the long term. Long-term protection principles have been expressed in a variety of different ways, from minimisation of burdens, to intergenerational equity, to the language of sustainable development, and the introduction of the term "reasonable assurance" when considering compliance with dose and risk criteria.

Table 3. **Evolution of IAEA regulatory principles and criteria for radioactive waste management and disposal**

Safety Series 99 (1989)	S Fundamentals 111-F (1995)	Joint Convention (1997)	WS-R-4 (2006)
Responsibility to future generations: based on minimisation of burden, Independence of safety from institutional control.	Protection of future generations: no undue burden and *intergenerational equity*.	Protection of future generations: to ensure that there are effective measures for the protection of individual society and environment, expressed in terms of *sustainability principle.*	Objective-Protection in the post-closure period objective: protection is optimised, taking into account social and economic factors, and a *reasonable assurance* is provided that dose or risk in the long term will not exceed the risk level used as design constraint.
Radiological safety expressed in terms of dose and risk upper bounds.	Protection of the environment in addition to human protection.	Criteria: based on intergenerational equity avoiding actions that impose *reasonably predicted impact and burden.*	Criteria: based on intergenerational equity. Recognition that doses for times farther into the future can only be estimated, uncertainties at very long timescales may dominate and care needs to be exercised in using criteria in the very long term. For such long times, indicators of safety other than dose and risk may be appropriate.

The evolution suggests that, although the responsibility to future generations remains as the main objective, its application should take into account the inherent difficulty of showing compliance with numerical doses and risk constraints over very long time frames, entailing thus the need for *flexibility in the requirements and paths for compliance demonstration*.

In addition, it should be borne in mind that the recently published general IAEA Safety Fundamentals, which supersede all previously published specific fundamentals including the SF-111F,

1. WS-R-4 was jointly sponsored by IAEA and the OECD Nuclear Energy Agency.

reflects the principle of protection of present and future generations in the following general terms: *people and the environment, present and future, must be protected against radiation risks.*

4.1 Focus on the IAEA Safety Requirement WS-R-4 and the new Safety Fundamental

Safety Standard WS-R-4 represents a high level of consensus on basic concepts such as optimisation of protection to *constrained optimisation*, taking as its basis previous international developments on the guiding principles for management of radioactive waste and geological disposal, such as ICRP references [7, 11-12], IAEA Safety Fundamentals 111-F [5] and the Joint Convention [8] and NEA [10], which together constitute a solid international guidance framework on the safety objectives and criteria for geological disposal. The recently published Safety Fundamentals document, SF-1, also adds some other general recommendations and views that may be useful concerning its application to the long-term management of radioactive waste. Some of the relevant statements of these IAEA Safety Standards are shown in Box 2, below.

Box 2. **Some relevant statements of IAEA Safety Standards WS-R-4 and SF-1**

WS-R-4

Constrained optimisation is the central approach adopted to ensure the radiological safety of the disposal facility, understood as a judgmental process, with social and economics factors being taken into account, conducted in a structured but essentially qualitative manner, supported by quantitative analysis.

- For very long times after the closure, *indicators* of safety other than dose or individual risk may be appropriate, and their use should be considered;
- Optimisation of protection for a geological disposal facility is a judgmental process that is applied to the decisions made during the development of the facility's design disposal facility. Protection can then be considered optimised provided that:
  - Due attention has been paid to the long-term safety implications of various design options at each step in the development and operation of the geological disposal facility;
  - There is a *reasonable assurance* that the assessed doses and/or risks resulting from the generally expected range of the natural evolution of the disposal system do not exceed the appropriate constraints, over time frames for which the uncertainties are not so large as to prevent meaningful interpretation of the results;
  - The *likelihood of events* that might disturb the performance of the geological disposal facility, so as to give rise to higher doses or risks, *has been reduced as far as is reasonably possible by the siting or design.*

Safety Fundamentals SF-1

Principle 7 on protection of present and future generations: people and the environment, present and future, must be protected against radiation risk. Additional statement regarding the long term:

- Where effects could span generations, subsequent generations have to be adequately protected without any need for them to take significant protective actions;
- The present system of radiation protection generally provides appropriate protection of ecosystems in the human environment against harmful effects of radiation exposure;
- Radioactive waste must be managed in such a way as to avoid imposing an undue burden on future generations; that is, the generations that produce the waste have to seek and apply safe, practicable and environmentally acceptable solutions for its long-term management.

5. From the NEA 1997 Córdoba Workshop to the 2006 NEA Paris Workshop: Where Do We Stand?

The conclusions of the 1997 Córdoba Workshop were summarised in [9] under the headings: "Radioactive waste disposal objectives and criteria", "Performance assessment issues" and "The regulatory process". Although a more complete description of the conclusions of this workshop has been shown in the paper by Alan Hooper to this workshop, a brief view is included below in order to highlight areas of progress during the last 10 years. Some of the issues addressed in Cordoba (under the above headings) were:

- *Radioactive waste disposal objectives and criteria*: references to the need for clearer guidance on basic dose/risk targets, limits and indicators, and on the meaning of risk in the context of safety assessment and regulation. There were also references to multiple lines of reasoning and multi-factor approaches, as well as to the need for guidance on the approach to protection of the environment as such.
- *Performance assessment issues:* references to issues such as the need for confidence building in the context of performance assessment for long timescales; the role of performance assessment as a support to licence applications and decision making.
- *The regulatory process:* references to development of a step-wise approach to regulation and a structured interface between implementer, the role of the public in the regulatory process, communication aspects to policy makers and the general public.

Most of the issues addressed at the 1997 NEA Córdoba Workshop remain as important aspects in regulating the long-term safety of radioactive waste disposal and a majority of them have deserved special attention at international and national levels, with significant progress having been achieved in many of the topics. Progress can be summarised as follows:

- New *international regulations and guidance* have been issued as shown in Table 1. Of particular relevance are: ICRP 81, the Joint Convention and the IAEA WS-R-4 [18], which address and develop new aspects and positions regarding the meaning and interpretation of the radiological protection objectives and criteria in the very long term.

- The development of *safety case* concept first at NEA [10] and [14] and later addressed in IAEA Safety Standard [18]. Increased and valuable experience in the development of safety cases at national and international level has been reached, taking account of the important role played by the NEA peer reviews of national programmes. In parallel, confidence arguments in the safety of geologic disposal have been broadly addressed, e.g. NEA references [10] and [14] and IAEA reference [18].

- Issues concerning the *regulatory process* have been dealt with in different international fora, such as the NEA RWMC Regulators' Forum and the RWMC Forum on Stakeholder Confidence [13] and [17], with the NEA Long-term Safety Criteria Initiative being a key development [22].

- *Decision making and communication* issues have deserved special attention in recent years, having been central to the work of the Forum on Stakeholder Confidence [15].

Finally, ethical considerations, important when deriving and applying regulatory requirements, have been discussed at international and national levels, leading to new perspectives and approaches when considering long-term time frames, e.g. references [21, 26-28].

6. Conclusions

There is a broad recognition that regulating the long-term safety of the disposal of long-lived waste is a difficult task, mainly because the very long time periods that need to be considered, the ethical duty to future generations, and the difficulty in demonstrating strict compliance with quantitative criteria expressed in terms of dose and risk.

Therefore, regulating the long-term safety of the disposal of long-lived waste it is a challenge for the radioactive waste community, which directly affects the regulators. The widening role of the safety assessment report, as a basis for decision making about geological disposal, means that this has to be understandable, at different levels of detail, to different audiences, including the general public.

Consequently, it is crucial that regulatory criteria and requirements are formulated in such a way that demonstration of compliance is facilitated in a credible manner, and it is important to ensure some level of international consistency on fundamental safety and radiological protection issues.

There exists an international guidance framework. The evolution of these guidelines over time demonstrates an evolving understanding of long-term implications, with the recognition that dose and risk constraints should not be seen as the sole measures of detriment, particularly beyond a few hundred years. There is therefore a need for greater emphasis on sound engineering and managerial practices and the introduction of new concepts and approaches which take into account social and economical and ethical aspects.

The fundamental objective of protecting present and future generations remains the priority in the development of any disposal facility. In demonstrating compliance with this objective, implementers are able to take account of new approaches and concepts that add flexibility to the compliance demonstration paths that may be used. The use of qualitative as well as quantitative arguments will enhance the understanding of the general public and of policy makers and will ultimately enhance confidence in the safety of the disposal system.

In this context, it will be necessary to explore implications of new regulations and to integrate technical aspects on predictions and expectations with ethical views on application of our obligations to future generations (see exercise of the annex to this paper). It would particularly useful to establish times frames in relation to the barrier functions, as is suggested in papers for Session 1.

And, finally, two useful maxims that should be borne in mind: “Never promise what you cannot deliver”, and “A mathematical theory in not be considered complete until you have made it so clear that you can explain it to the man you meet on the street” (D. Hilbert).

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Annex

Views and approaches of National Advisory Organisations regarding our responsibilities for the long-term protection of future generations may be of help to a better and practical understanding and explanation of the long-term implications.

NAPA **1997[26]** Principles for inter-generational decision making	**EKRA** **2000[27]** A hierarchy of three ethical criteria	**KASAM** **2004 [28]** Ethics of sustainable development: four principles of justice
Four principles: • Trustee Principle • Sustainability Principle • Chain of Obligation Principle • Precautionary Principle	• *Safety* of man and the environment • *Fairness*: in every democratic decision • Individual and social *acceptance*	• Gradual obligations regarding future generations • *Strong Principle of Justice*: future generations have a quality of life at least equal to ours • *Weak Principle of Justice*: Future generations can satisfy basic needs • *Minimal Principle of Justice*: moral obligation to respect future generations, not jeopardise possibilities for life

Personal Composition: Integrating technical predictability of some elements of the Geological Disposal System and the KASAM justice principles based on references [16] and [28].

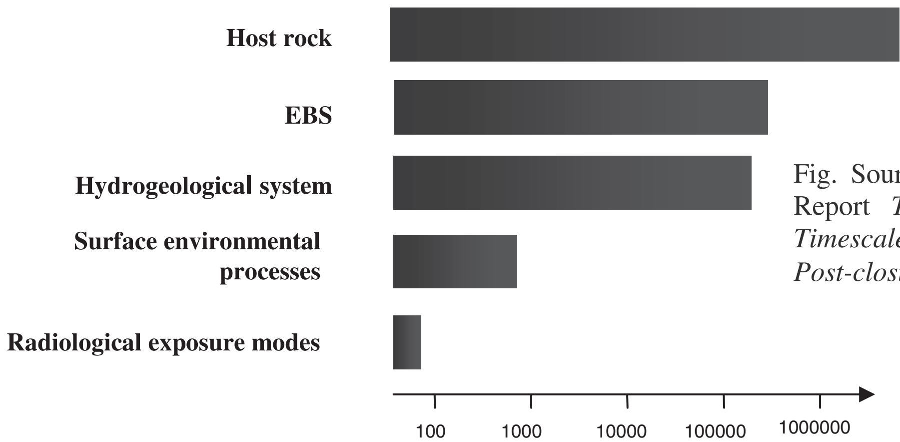
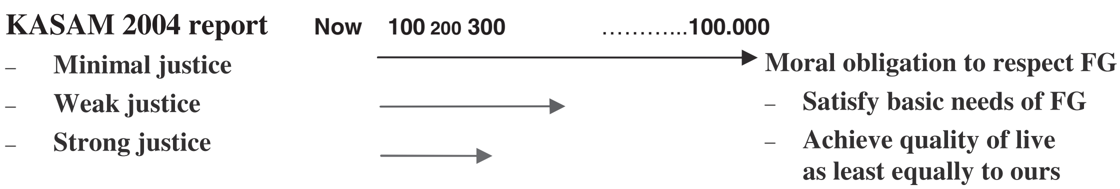


Fig. Source: NEA (IGSC) Report *The Handling of Timescales in Assessing Post-closure Safety* (2004).

The limits of predictability of various aspects of a geological disposal system (box 1 of the mentioned source)



Three timelines that define the main applications of the principles of justice in time (Figure 9.2 of KASAM report)

Clarification notes on the integration shown in the previous composition

The figure of NEA report [16] gives a schematic illustration of the limits of predictability of various aspects of a geological disposal system (note that actual timescales are site and design specific). It illustrates that:

- The evolution of the broad characteristics of the engineered barrier systems (EBS) and the host rock are reasonably predictable over a prolonged period (10E-5 or 10E-6 years, say, in the case of the host rock). There are uncertainties affecting the engineered barrier systems and the host rock over shorter timescales, but these can, in general, at least be bounded with some confidence.
- The patterns of groundwater flow (the hydrogeological system), in particular near the surface, can be affected by climate change and are thus somewhat less predictable.
- Surface environmental processes and radiological exposure modes are not generally considered to be parts of a deep geological repository system, but are relevant for evaluating dose and risk. These are less predictable still, being affected by ecological change, human activities and individual habits, which are highly uncertain, even on a timescale of a few years.

KASAM Principles of Justice [28]

"Spent nuclear fuel will be hazardous to human health and the environment for hundreds of thousands of years, in other words, until the radiation has decayed to a very low level.

- **The minimal principle of justice** requires that we do not jeopardise future generations' possibilities for life. This means that we – the generation which has enjoyed the advantages of nuclear power – have a moral obligation to create robust conditions for isolating the hazardous waste from the natural ecological cycle for a very long time. A repository for spent nuclear fuel must therefore be constructed in such a way that it does not require any maintenance or monitoring, even in the long term. At the same time, future generations must be given the possibility to monitor the repository and to improve the final disposal system.

- **The weak principle of justice** states that we also have a responsibility and duty to use natural resources in such a way that future generations can satisfy their basic needs. This means that we should not unnecessarily prevent the freedom of action of future generations – and especially those living *up to about 300 years into the future* – from, for example, using the waste as a resource, namely, to enable retrieval. However, this only applies on condition that the long-term safety is not reduced. Our obligation to not risk subjecting future generations to damage is therefore greater than our obligation to take into account the possibility that a not too distant generation might wish to retrieve the waste for some purpose.

- **The strong principle of justice** entails being responsible for our actions so that subsequent generations – *up to about 150 years into the future* – can be expected to achieve an equivalent quality of life as we have, namely, so that they can enjoy life in the way that we have been able to in our current situation. The accumulation of the financial resources in the Nuclear Waste Fund, with the aim of ensuring that these financial resources are available for the final disposal of Swedish nuclear waste, contributes to our possibility of assuming this responsibility."

EXPECTATIONS FROM IMPLEMENTERS

E. Biurrún[1], **P. Zuidema**[2] ***et al.***
[1] DBE Technology GmbH, Germany, [2]NAGRA, Switzerland

Introduction

Although fairly limited (USA and Germany) there is important experience available in disposing of waste in deep geological repositories at an industrial scale. In the USA the Waste Isolation Pilot Plant continues receiving contact handled long-lived LLW for disposal at present, and will soon start receiving ILW, which requires remote handling and disposal. In Germany, deep geological disposal of low and intermediate level waste started in 1968, and went on at two different facilities until 1977 and 1998 respectively. In both German facilities also waste requiring remote handling and disposal was received. Disposal in the last serving facility was phased out in 1998, both repositories are now in the phase of decommissioning and closure.

Remarkably, the operating experience of these two countries, and that of other countries with advanced repository development programmes, has played up to present a very limited role, if any, in the discussions going on at different levels as to how to regulate this activity, e.g. in the Regulators' Forum of the OECD/NEA. This is so far remarkable as operating deep repository mines entail a number of technical challenges requiring a kind of thinking totally alien to the nuclear field, from which the staff of most regulators stem, and thus their experience. It is for that reason that the opportunity to present the view of organisations directly involved in the repository work is very much appreciated.

What does an implementer need?

Repository development would usually be a massive industrial endeavour, requiring the deployment of significant resources in manpower and financial means. Moreover, the effort must be maintained at a high level for a period of time covering at least decades, probably more than a century. Setting up the scene for such work, i.e. defining the regulatory framework within which the activity would evolve, is therefore not a trivial task.

And that brings us right to the core of the difficulties. One essential need of the implementer is a ***stable regulatory framework*** that allows making decision on the basis of regulations, facts, and arguments that persist being valid for periods of time in line with the duration of the task. The public call for taking into account the aspirations and needs of the public, inherent to democratic society, is to some extent in conflict with the above requirement. Albeit an evolution of the regulatory system will be unavoidable and to some extent beneficial, it would be a primarily important task for the regulator to still maintain the degree of stability needed for long-term work planning and execution.

Regulatory criteria and ***guidance*** are a vital input for the implementer to:

- develop the repository system;

- compile the licensing documents (safety case, etc.); and
- define the process (design, RD&D, analyses/syntheses, decision making).

The core of the regulatory framework shall include definition of the ***requirements*** the repository system must fulfil. ***Guidance*** on how to translate such requirements into concrete instructions is most helpful. The required ***licences*** must be clearly defined, the ***yardstick*** to be used to evaluate compliance of the licence application with the requirements must be defined in advance and known to the implementer.

Furthermore, the ***decision-making process*** as a whole must be clear from the very beginning, and must be as ***stable a system as possible***. In this regard, a ***stepwise approach*** to repository implementation is receiving in recent times increasing attention. From the implementer's point of view this development appears somewhat remarkable, since there are a number of steps that must be carried out in the process of repository development, and these can hardly be carried out differently than in a consecutive manner. In other words, there is no other way to implement a deep geological repository as in a number of steps, which include: the site selection, the surface and thereafter the underground exploration, licensing, operation, and later closure.

The aspect of concern from the point of view of the implementer is that of:

- the decision points between steps;
- the rules to be followed; and
- the requirements to be fulfilled.

to pass from one step to the subsequent one. These last mentioned aspects are of paramount importance because they touch core principles of the legal system in democratic societies, as are ***legal certainty***, ***property protection*** and protection against arbitrariness.

Repository development requires a massive investment from the time when work for accessing the underground starts. The costs are to be borne by the waste producers, a duty usually enforced by law. Correspondingly, any decision affecting the fate of an ongoing repository project will need to be based on objective, substantiated criteria, otherwise it will violate above legal principles and thus the rights of the waste producers. With this, participation by third parties (stakeholders) in the decision-making process, the ***stepwise approach***, and specifically the passing from one step to the other, will require clearly defined rules that take also care of protecting the rights of the waste producers. Such rules will therefore tend to limit the rights of third parties to steer the process by intervention. While continued public acceptance would be a great asset for any repository project, the loss of it at some stage other than the starting phases cannot be a reason to discontinue the process when significant investments have already been made. Stopping the process, or unilaterally changing the rules, would then be equal to depriving the waste producers of their investment, thus equalling expropriation, which in a democratic society is only allowed under very restrictive conditions.

Moreover, protection against arbitrariness will strongly limit the possibility to stop or redirect the repository development process once under way. Society's subjects, including the waste producers (the paying polluters), need to be able to trust that regulatory decision (as with other decisions of executive bodies of Government) would not be reverted or changed unless there are serious concerns requiring it. Such serious concerns will certainly include those regarding safety, but can hardly comprise "soft" criteria such as, e.g. changing public acceptance. Therefore, the intention of giving external stakeholder ***strong influence on the process*** or even ***real control*** on it would offend important, constitutionally granted rights of the waste producers, thus requiring careful consideration. An example of how this conflict has been solved is the nuclear power plant licensing in the past in

Germany. Here a stepwise approach was followed in which in an initial licence the general concept of the plant, the site, and related matters where fixed. To rule out arbitrariness at later stages the utilities were granted with the first license the enforceable right to obtain all the others licenses, provided the safety objectives were met. A similar procedure for repository licensing appears at first sight quite acceptable. But great care must be taken in its implementation to make it impossible that the licensing process is blocked to a standstill by litigation against it.

A further aspect that has recently received attention is the ***optimisation of protection***, as recommended in the ICRP Publication No. 81. Optimisation of protection in the praxis of repository construction and operation requires

- objective criteria and guidance

as to what to optimise, and the corresponding

- yardstick

to decide when the optimisation process should stop. While this task appears for the ***repository operational phase*** rather straightforward, there are still specific aspects often overlooked in the public discussion. A clear example of that is that of ***retrievability***. Very detailed studies have conclusively shown that waste disposed of in a repository following the concentrate and confine approach can always be retrieved. While in certain situations the necessary effort will be high, in most cases waste retrieval will be relatively easy and straightforward. With that, the reasons for keeping a repository open for a large period of time must be seen in the political and in the public acceptance field, i.e. are related to feeling comfortable with the fact that we can react more easily in case it is needed.

On the other hand, keeping open an aging underground facility entails quite concrete dangers for health and life of the repository staff. Some accidents are likely to happen in spite of all efforts to prevent them; the repository staff will unavoidably be exposed to radiation. Correspondingly, it must be clear to all participants, and it must be communicated to the public, that the retrievability requirement aimed at buying peace of mind of stakeholders will mean that people will actually receive a radiation dose, that will be subject to the rather high risks of underground operations. Retrievability comes at a cost in terms of risk and health detriment of some people, this cost will be rather high, and society will certainly have to pay it.

It is because of facts like this mentioned one that from the point of view of the implementer the rather generic ***optimisation requirement*** needs to become more ***concrete***, that ***guidance*** is needed. How should a "virtual" gain in the far future be weighed against actual detriment incurred today? Is it really justifiable to strive for a reduction of the calculated dose an individual would potentially receive in the far future, with all the associated uncertainty, and to achieve that potential reduction to expose the staff to an actually received dose? What does optimisation in this context means? Is it really fair to pay great attention to the people that ***feels*** threatened by final disposal and completely disregard the needs and aspirations of the implementer, the people that take real risks to serve society? The regulator needs to achieve a fair balance of all these aspects.

While striving for ***best possible safety*** appears at first sight a valuable objective, there are limits to what can and needs to be achieved, and much more serious limits to what ***can be demonstrated*** that will be achieved. In the past the aspect of how to provide convincing proof, including legally defendable proof, that the protection objectives are met have received little or no attention. While scientists usually have great confidence in their performance assessment calculations, this doesn't necessarily mean that they will be ***defendable before a court.*** And this will most likely be necessary, as the examples of the only two hitherto licensed deep geological repositories – the WIPP in the US and Konrad in Germany – have shown. Construction does not immediately follow licensing (or permitting for the WIPP). In-between there is a lengthy period of litigation. Therefore, we need to pay attention from the very beginning to far-reaching legal consequences of how waste disposal is regulated and to the legal pitfalls that could unintentionally be created while regulating waste disposal.

Last but not least, an important aspect is that the regulatory system for a repository shall be ***clear and consistent***. It is important to be consistent with other environmental regulations and the corresponding permitting procedures, especially with analogous or interrelated regulatory fields as the underground disposal of hazardous chemical waste and the protection of groundwater resources. In many situations the radioactive waste will contain also toxic substances, e.g. some organics or heavy metals. Such materials are per se noxious and in some cases may even overshadow the waste radio-toxicity. But common environmental regulation does not usually deal with the long time frames that are customary in radioactive waste disposal. Achieving consistency is therefore a difficult to meet but necessary objective.

How to implement these needs – the importance of dialogue and credibility

Ideally, a ***fluent dialogue*** and a ***fair interaction*** between the regulator, the implementer, and other concerned parties will be the best-suited and also sufficient platform to achieve the common objective of safe final disposal. Unfortunately, this is easier said than implemented, as all stakeholders have to get used to it and there are few precedents, and political short-term interests may well interfere. Institutions like the Regulators' Forum are certainly a suitable platform, provided it is actually ensured that all concerned voices are really heard.

On the other hand, regulating for the long-term safety of radioactive waste geologic disposal has an important technical-scientific component that it is very difficult to communicate to the general public, if at all possible. Licensing a repository will be to certain extent an act of faith on long-term predictions that the protection objectives will be met. It will entail a great deal of judgement by the regulator and other involved parties that can hardly be objectively substantiated, and even harder be communicated to the non-technical audience. Therefore, the ***credibility of the regulator*** is of paramount importance, and for that its ***absolute independence*** from day-to-day politics is a must. It is on the basis of this credibility that the regulator would be in a position to defend its regulatory judgement and its regulatory decisions. With this credibility ensured, and with a ***clear definition*** of the regulator's responsibilities and the roles and responsibilities of other stakeholders, it should be possible to successfully address safe deep geological disposal.

AN OVERVIEW OF REGULATORY APPROACHES

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Abstract

International standards

ICRP-81

The objective is to protect future generations to at least the same level as current generations. Compliance with that objective is measured using a single dose constraint value of 0.3 mSv/a (or an equivalent risk constraint of $2x10^{-5}$/a). Nevertheless, the interpretation of the calculated doses that are compared with this constraint changes with time. These doses are considered to be measures of health detriment for the first few hundred years, but only indicators of repository performance at longer timescales.

Two other means of recognising this change in interpretation are suggested: (a) a cutoff of 1 000 to 10 000 years may be used for quantitative forecasts; and/or (b) qualitative judgements may be introduced at longer timescales.

ICRP-81 also recognises the usefulness of alternative or supplementary criteria such as Best Available Technology (not entailing excessive cost), particularly at long timescales where direct quantitative measures of detriment are unavailable.

IAEA WS-R-4

As in ICRP-81, a single criterion is recommended regardless of timescale. However, it is recognised that at long timescales such a criterion is no longer a reasonable basis for decision making. As above, two means of dealing with long timescales are suggested, although these are not the same as the two methods proposed in ICRP-81: (a) use of the criteria as targets rather than as hard limits (exceeding the criterion need not result in rejection); and (b) possible replacement of the initial criterion with a different one, namely comparison with natural background levels.

National criteria

With the exceptions noted below, the national criteria reported in the responses to the questionnaire in most countries do not explicitly recognise differences in criteria depending on timescales. The clearest example of this is in the Swiss criteria. Despite the recognised fact that dose calculations for the distant future are not to be interpreted as effective predictions of radiation exposures of a defined population group, the specified limits (0.1 mSv/a for high probability scenarios) are never to be exceeded.

Another example of a criterion that remains the same regardless of timescale is the risk target of 10^{-6}/a used in the United Kingdom. However, it is important to note that this number is used as a target, because for repository post-closure, compliance with a limit could never be proven absolutely.

Five examples of explicit recognition of timescales in criteria follow:

Germany: Demonstration of compliance with the dose constraint criterion (0.1 mSv/a) is required up to a cutoff timescale of one million years, beyond which a scientifically supported prognosis is no longer considered feasible.

Finland: A dose/risk constraint (0.1 mSv/a) applies for "several thousand years". For longer timescales, dose/risk constraints are replaced by radionuclide-specific release constraints, i.e. there is an upper limit on the timescale over which dose/risk limits are applied.

France: A dose constraint of 0.25 mSv/a is applied as a limit for 10^4 years. For later periods, this criterion is used as a "reference value" (i.e. a target rather than a limit).

Sweden: A quantitative assessment against a risk criterion of 10^{-6}/a (.015 mSv/a) is required for timescales up to 1 000 years. Beyond that time, for timescales up to 10 000 years or longer, a more general assessment of the repository's protective capability against various possible sequences is required.

United States: Prior to 2005, demonstration of compliance with a quantitative dose limit (0.15 mSv/a) was required only for 10^4 years; the quantitative standard did not apply after that time. Under changes proposed in 2005, a different (3.5 mSv/a) quantitative limit would be applied for timescales between 10^4 and 10^6 years. There is no requirement proposed beyond 10^6 years because of the impracticability of making meaningful calculations beyond that time.

So far, we see that there is great variability in how regulatory criteria deal with long timescales. There is not a clear consensus on whether a single criterion can be used for all timescales, or if this is not considered appropriate, what to do instead.

In some cases, supplementary criteria are used. For example, if we consider dose and risk calculations to be no longer meaningful at long times, we may require calculations of other performance indicators such as radionuclide fluxes in the environment. Alternatively, as in the UK, dose and/or risk may be used as a target for optimisation (ALARP) rather than as a hard limit.

A different form of optimisation such as BAT(neec) may be applied in some situations, as mentioned in ICRP-81. Here the optimisation ("best available technology") is applied directly to the design elements, rather than based on the results of a dose or risk calculation as in ALARP. We may choose to insist on various design criteria (e.g. no loss of containment for 1 000 years, a specified number of engineered barriers, restrictions on the geological setting). Any of these may be used either to supplement dose and risk criteria or in some cases and at some timescales, to replace them. *There is no consensus evident in the way different regulators use these criteria.*

All of the above discussion relates to "normal" (i.e. high-probability) scenarios. There is an equivalent level of variation in how less likely scenarios are treated: probability cutoffs, qualitative discussions of low-probability events, different dose targets for different probability ranges, aggregated vs. disaggregated risk and consequence calculations.

In addition to uncertainties related to the choice of scenarios to analyse, there are other uncertainties, for example in physical parameters which enter into the analysis. Some regulators expect these to be handled in a deterministic "conservative" fashion, others by means of formal uncertainty and sensitivity analysis.

There is thus a great lack of consensus among regulators at the level of detailed criteria and requirements. There appears to be little agreement on the basis for criteria (absolute risk; dose based on current radiation protection criteria; or dose based on comparisons to natural levels); on whether and how these criteria should change with timescale; and on how to address sources of uncertainty other than long timescales. This diversity might be because each country has different ultimate safety goals, or it might be that we all have the same underlying goals but choose to approach them by different paths. The only way to find out, and thus to determine whether the observed differences in criteria are meaningful or superficial, appears to be to seek a common understanding about shared (or unshared) goals at a deeper level than that of the criteria.

A PRAGMATIC VIEW ON THE ROLE OF OPTIMISATION AND BAT IN REGULATING GEOLOGICAL DISPOSAL

Björn Dverstorp
Swedish Radiation Protection Authority

Supporting draft notes

Premises – Unique features of geological disposal

Dose and risk targets or other criteria relating radionuclide releases to consequences for humans and the environment provide yardsticks by which the acceptability of the repository can be determined. Performance assessment calculations provide numbers for comparison with these criteria. However, risk analyses for geological repositories will always be associated with uncertainties, especially for distant time periods after closure and regarding climate, biosphere conditions and human society. But also due to incomplete site data and the need for extrapolation of measurements and models into the distant future. Further it will not be possible to check the results of the performance assessment calculations thousands of years into the future. Therefore there is a need for additional supporting arguments in the safety case (or licence application) to convince the regulator and to support decision making.

Supporting arguments could be given regarding quality assurance, confidence, robustness, scientific methods and so on, and the list could be made long. The question could also be asked, how can we know that the proponent has done as good a job as reasonably possible. Has the proponent taken into consideration possible means of improving the expected repository performance? It is in this context that the principles of optimisation and BAT are important regulatory (and societal) tools!

Supplementary requirements to dose and risk

In SSI's view, requirements on the use of optimisation and BAT are necessary supplements to a risk or dose standard. Both principles focus on the proponent's work on developing the repository system, rather than the end results of the safety calculations that should be compared with the standard. Optimisation and BAT are applicable to the whole process of developing a final repository, i.e. all steps from siting, design, construction, operation to closure of the repository. However, the application of these principles is subject to societal and economical constraints as will be discussed later.

In SSI's guidance (SSI, 2005) we give the following advice on how to apply optimisation and BAT: Optimisation is defined as a tool to minimise risk, based on the results of risk calculations. This means that recurrent preliminary safety analyses, carried out by the implementer during the stepwise development of the repository system, should be used to evaluate how different sites, design options etc. best contribute to reducing future risks.

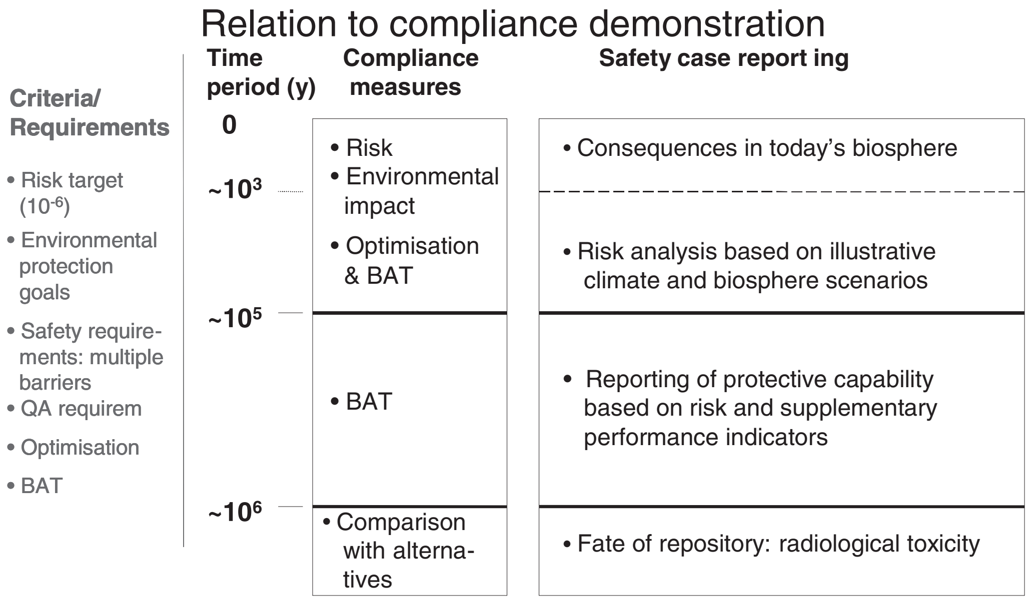
However, as mentioned above, risk and dose calculations will always be associated with uncertainties when looking far into the future. For these situations, and also for early stages of repository development when there is limited data from sites and the engineered barrier system (EBS), the concept of BAT is a more appropriate tool. BAT focuses on more robust measures of repository performance, aiming to hinder, reduce and delay releases of radioactive substances from both the engineered and the geological barriers, and is therefore less sensitive to speculative assumptions on climate and biosphere conditions in the distant future.

In case of a conflict between BAT and optimisation, measures satisfying BAT should be prioritised. For example, the risk analysis may suggest that a repository solution leading to early releases is acceptable if the radioactive substances are diluted in a large lake or the sea. In such a case a repository solution providing containment, according to the principle of BAT, should be prioritised.

Application of optimisation and BAT on different timescales

The conditions for estimating risks from a geological repository are different for different timescales. Some elements of the risk analysis become speculative already after few hundred years after closure, for example human society and living habits. After a few thousand years the uncertainties regarding the human environment (the biosphere) will increase, which renders calculation of radiation doses and risk even more uncertain. In the time perspective of 100 000 years one could expect dramatic climatic changes with glaciations and large sea-level fluctuations in the Scandinavian region. Other elements of the risk analysis, such as the evolution of the basement rock and the engineered barriers, can be expected to be more stable over long time periods. These are some of the considerations behind SSI's guidance on the reporting of risk analyses and other radiation protection arguments for different time periods, summarised in Figure 1.

Figure 1. **Role of optimisation and BAT in compliance demonstration (based on Dverstorp et al. 2005)**



The left hand side of Figure 1 lists regulatory requirements and criteria including the risk target, environmental protection goals, safety requirements on barriers, and the use of BAT and optimisation. These requirements are in principle applicable to all timescales. However, when assessing the repository's compliance with these requirements it necessary to acknowledge the different conditions for evaluating repository performance discussed above.

Three main compliance periods can be identified. The first is the period over which calculations of dose and risk has a meaning for compliance evaluation. The length of this time period may vary depending on country and setting of the repository site, but in Swedish guidance quantitative risk calculations are expected for the time period of one glaciation cycle or approximately 100 ka (for spent nuclear fuel repositories). For this time period the proponent should present quantitative risk and dose calculations for comparison with the risk standard. The calculated risk (and environmental impact) is the main compliance measure for this time period, but the application of optimisation and BAT are important supplementary arguments.

For the time period beyond 100ka, after a glaciation, risk calculations become more speculative due to large uncertainties in climate and biosphere conditions, hence compliance demonstration based exclusively on a comparison of calculated risks with the risk target will not be meaningful. The compliance discussion for this second compliance period may instead be based on a combination of arguments including more robust measures of the repository's protective capability, such as different measures of barrier performance and activity fluxes. Indications of disturbances of the repository's protective capability should be reported together with a discussion on potential measures for improving the repository performance. Hence, for these long time periods SSI's evaluation of compliance will focus more on the application of BAT than on the uncertain results of a quantitative risk analysis.

At some point in the distant future, even analyses of more robust repository performance measures become speculative and meaningless. Further, it is hard to foresee any measures that could be taken in the design of the repository that would counteract the very long-term global geological processes, for example repeated glacial erosion that eventually may expose the waste to the human environment. Therefore SSI does not ask for a reporting of radiological consequences after 1 million years after closure of the repository. However, a simple analysis of the fate of the repository and the very long-term consequences of concentrating uranium in geological formations may provide an important basis for high-level comparison with alternative waste management options.

Criteria for optimisation and BAT

Because we cannot foresee exactly what issues that will appear in the proponent's safety case, it is more or less impossible, a priori, to define a comprehensive set of criteria for BAT and optimisation. So qualitative judgements are unavoidable! However, a stepwise process of developing a repository makes it possible to evaluate BAT and optimisation along the way. One example of that is the Swedish system with reporting and regulatory review and government decision of SKB's RD&D programme every third year – where design choices and other important decisions in SKB's programme are scrutinised. Nevertheless it is important that the safety case/licence application contain a road map of the most important BAT considerations, i.e. the ones really affecting safety, throughout the development of the repository system so they can be reviewed and presented to the decision-makers.

Constraints for the application of optimisation and BAT

There are of course constraints that set boundaries for what can be expected in terms of optimisation and BAT. The principle of voluntary participation in the Swedish Nuclear Fuel and Waste Management Co's (SKB) site investigations on part of the municipalities is one example of a societal constraint on site selection – the best site is only the best among the available sites. In some countries siting is even more restricted. An economical constraint (in Sweden) is the availability of funds in the nuclear waste fund, which is determined by recurrent government decisions on fees on electricity produced by the NPPs. Technical constraints could be availability of technology and the effectiveness of various measures for enhancing the repositories' protective capability.

BAT and future human action

Future human action (FHA) is a direct consequence of geological disposal and any attempt to estimate probabilities and consequences will be very speculative. Therefore Swedish guidance states that FHA scenarios should be reported separately and should not be included in the risk summation. The purpose of FHA scenarios is instead to provide a basis for identifying measures to reduce the probability and consequences of the human disturbances, according to the principle of BAT, e.g. by increasing repository depth or avoiding mineral deposits. FHA scenarios may also be used for high-level comparisons of geological disposal with other waste management options, to compare inevitable risks.

Summary

Optimisation and BAT are important regulatory (societal) tools for ensuring an attitude of doing as good as reasonably possible, i.e. important supplements to the quantitative yardsticks dose and risk. Critical BAT and optimisation considerations may become an important part of the decision basis and should consequently be presented in an understandable way to the decision makers.

Examples of remaining issues in developing the concepts of BAT and optimisation for geological disposal include:

- How best to report on optimisation and BAT considerations in a safety case/licence application?
- How to strike an appropriate balance between weight given to BAT/optimisation versus risk and dose calculations for different time periods? This is particularly relevant for situations where the calculated risks and doses are close to the regulatory targets.
- How to define available technique or technique that can reasonably be developed?

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THE HANDLING OF UNCERTAINTIES IN THE EVALUATION OF LONG-TERM SAFETY: A FEW EXAMPLES FROM THE SWEDISH REGULATORY FRAMEWORK AND SWEDISH PROGRAMME FOR DISPOSAL OF SPENT NUCLEAR FUEL

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Abstract

The handling of uncertainties is a key element in the evaluation of long-term safety. There are many categories of uncertainties and it is unavoidable that some of them will increase as a function of time in the analysis of the extremely long timescales normally addressed in post-closure safety assessment. However, uncertainties must be shown to be constrained or otherwise appropriately handled prior to decisions to proceed with disposal programme.

The Swedish Nuclear Power Inspectorate's regulation SKIFS 2002:1 states that the most important requirement is that uncertainties are described and handled in a consistent and structured manner. The impact of uncertainties should be evaluated by sensitivity analysis, covering for instance the description of barrier performance and the analyses of consequences to human health and the environment. The guidelines state that there should be a classification of uncertainties into different categories (e.g. scenario uncertainty, system uncertainty, model uncertainty, parameter uncertainty, spatial variation in the parameters used to describe the barrier performance of the rock).

Uncertainties may be handled in many different ways depending on their character:

- eliminate if possible;
- account for in the design;
- reduce or constrain as much as is reasonable;
- circumvent;
- accept but discuss openly (regulator may prescribe stylised approach).

Elimination of some uncertainties may be done by site selection (e.g. avoid permafrost in future climate states) and repository design (e.g. avoid canister failure from localised corrosion by selection of corrosion barrier material). For some aspects of barrier performance (e.g. mechanical integrity of canister) recommended safety factors may be used to account for conceptual uncertainties in models and geometric uncertainties. However, safety factors do not necessarily have to be applied for highly improbable loading conditions.

Uncertainties can in some case be reduced by non-destructive testing (e.g. canister defects), more experimental data (e.g. site measurement, long-term experiments with engineered barrier components) and additional research. In spite of these efforts, a range of uncertainties related to the extreme complexity of the system in consideration must be handled through conservative simplifying assumptions. A thorough justification of such assumptions is needed, since there may be other implications of such assumption than those originally envisaged. Finally, some uncertainties are not readily reducible or possible to circumvent but are a consequence of the selection of geological disposal (future human actions scenarios, intrusion, etc.). They still need to be analysed and discussed.

Appendix 3

RAPPORTEURS' REPORTS

SESSION 2: REGULATORY RAPPORTEUR'S COMMENTS

Allan Duncan
United Kingdom

This report addresses five selected observations, from the perspective of a regulator.

1. Carmen Ruiz presented the expectations and recommendations of the international bodies (ICRP, IAEA and NEA). As expected, the work of these organisations is of a high technical quality. For the most part, our technical colleagues perform this work for those bodies responsible for the licensing and enforcement elements of the regulatory process. But this work has hardly been mentioned in the context of the current workshop discussion.

This may be because these international bodies address those technical issues (as they perceive them) that are particularly relevant to the licensing element of the regulatory process. By contrast, this workshop approaches such issues in a broader context of the more fundamental issue of what society intends to achieve when disposing of long-lived hazardous waste. In this regard, this NEA effort may be unique in that its focus is the policy and basic objectives of regulation itself. We have welcomed the input of professional ethicists and social scientists into a broader based discussion with technically-oriented regulators and implementers. We believe that this broader context is essential to advancing the thinking about regulation of long-lived waste disposal, particularly in regard to the delivery of sustainable development, which is the basis for the Joint Convention.

2. With respect to the ethical dimension of our discussions of the societal objectives for disposal of long-lived waste, Patricia Fleming and Carl-Reinhold Bråkenhielm set forth various ethical principles that might be relevant. Patricia Fleming posed two key questions, i.e. "What **is** the objective?" and "What **ought** it be?" It is not apparent that we have answers to either of these questions that are sufficiently convincing for the public in a number of member countries. She did recognise, however, that this is generally for the politicians and policy makers to decide, and that the ethical guidance might not be the ultimate determinant of policy. Nevertheless, it seems to be important for public confidence that these questions are addressed openly and that the answers are robust when examined from the full range of perspectives brought to bear in the decision-making process.

It was clear, too, that, as a group, ethicists are not of one mind about such fundamental issues as the nature and extent of our duties to future generations. This is critical for what implementers must design, build and operate, and for what we, as technical regulators, responsible for the licensing process, will use to evaluate and judge safety. Over the last several decades, technical regulators have done their best to carry out their regulatory duties to protect future generations, in an ethical manner, consistent with their authority, and in a manner appropriate to their specific cultural and national context. For the most part, they did so without any explicit or internationally accepted, starting point of ethical principles and objectives.

3. Andrew Blowers and Enrique Biurrun developed this theme further in discussing timescales, distribution of resources and intragenerational equity. In this general context, Prof. Dermange of Switzerland (as reported by C. Pescatore) doubted the merits of considering the "needs and aspirations of future generations." While the idea of 'Sustainable Development' may be a convenient, political catchphrase, Dermange believes that it may be meaningless for any practical purpose.

Andrew Blowers introduced the ideas of geoscientific and socio-cultural time and implied that we may have the balance wrong as between protecting the interests of people in the very long term and those living in the more immediate future. This reflected Patricia Fleming's earlier ethical observations and raised questions about our ability to predict and influence the far future. Enrique Biurrun made a similar point about applying resources to long-term safety concerns that could better serve to protect current generations. He also cited the very practical example of deploying mine operators, and incurring actual, current casualties, to maintain retrievability simply for public peace of mind about uncertain, potential consequences in the far future.

4. The issue of 'harmonisation' was raised in discussion. We need to make clear what the group does and does not support with respect to harmonisation. The LTSC group would support "harmonisation" only insofar as developing a common understanding of the policy objectives to be achieved in disposal of long-lived waste. The group does not seek, and would not support, the prescription of a uniform approach for all regulatory systems. Experience of general environmental regulation, in the European Union at least, suggests that member state's regulatory programmes achieve fundamental objectives at levels that are fully protective. However, the details of how each national programme achieves these objectives are necessarily a function of national culture and psyche, and are not amenable to harmonisation. This was confirmed by Klaus-Jürgen Röhlig in connection with the European waste regulators' study of the safety case for radioactive waste disposal.

5. With respect to the objectives for disposal of long-lived hazardous wastes, there was some discussion about the inconsistency between the apparent acceptability of relatively short-term objectives for chemically toxic wastes and the insistence upon very long-term objectives for nuclear wastes. It has to be emphasised that the only merit in pursuing such discussion would be to discover the specific concerns which drive the public's acceptance of such vastly different treatment of wastes with analogous hazards.

SESSION 2: CHALLENGES FOR REGULATORY POLICY AND DECISION MAKING

Juhani Vira
Finland

I am trying to summarise Session 2 of the LTSC Workshop in terms of three questions:

- What has changed (in relation to regulations)?
- What are the implications of these changes to regulations?
- What are the implications of these changes to regulators?

My perspective is that of the applicant, i.e. the implementer who has to apply the regulations in the licensing activities.

What has changed?

In the background document NEA/RWM(2006)13 of the workshop it is said that "one of the most striking aspects from the point of view of long-term criteria for disposal has been the evolution of the principles upon which the regulations are based". A reference is made to a table showing regulatory terms from a number of international documents from the period 1989 to 2006. However, aside from some new concepts like sustainable development, the table hardly substantiates the argument about major changes in the fundaments of the regulatory thinking.

It is true that there are a number of new international recommendations and guidelines published in the past one or two decades. Likewise, a number of new safety assessments have been published, and in some countries the licensing phase has already begun for a high-level waste repository. During the past ten years or so much emphasis has been given to the social and societal aspects of nuclear waste management and, in general, it is now understood that all the stakeholders affected by the waste management solutions should somehow be engaged in the decision-making process. New policy concepts, such as sustainability, have been introduced and it seems that sometime the contents of these concepts have remained vague despite the frequent use of these terms in the policy discussion. In addition, in the United States of America, a proposal for new regulatory rules has been drafted by the Environmental Protection Agency. This proposal now suggests different dose limits for different time periods; i.e. higher individual doses would be accepted for generations living far away in the future. The proposal is interesting in the present context as it may be in contradiction to the principle of providing the future generations at least with the same level of protection that is now considered adequate for the current generations.

Nevertheless, it seems that little has changed in the fundamentals on which most of the current regulations (or draft regulations) are based. This workshop provided new insight to the philosophical background of the fundamental principles, and important comments were made on the present practice of application of these principles, but the discussion hardly raised serious reasons for fundamental changes in the principles themselves. On the other hand, the discussion showed clearly some problems in the application of the principles and a need to clarify the contents of some concepts introduced in the regulations.

Implications for the regulations?

The ethical basis of the fundamental principles was revisited in several high-quality presentations at the workshop. We heard about different theories and ways of reasoning about intergenerational justice, but the conclusions on intergenerational justice still seemed to be very much the same as in the 1970s and 1980s when there was lively discussion of similar issues in various applications of operational analysis. From the ethical point of view it is hard to defend policies that explicitly set different standards for the level of protection in different time periods. However, since our capacity to guarantee the desired protection level for the generations living very far away in the future necessarily becomes less with time, the balance of spending money for near-term protection and long-term protection, respectively, deserves careful thinking. The toxicity of high-level nuclear remains practically for good, but it will never be possible to give strong guarantees of perpetual protection. According to the presentation heard in the session, in some countries the required level of protection can be demonstrated for 1 to 10 million years, but, in general, the possibility of control diminishes with time. In some countries the evolving geologic conditions will make the predictions of the repository performance highly uncertain in the far-away future.

Therefore, although the ethical principle of equitable protection of all generations is accepted, the diminishing possibilities for control and the growing amount of uncertainty in our descriptions of the future evolution of the disposal system should be acknowledged in the regulations. In practice this would mean that the protection targets may be kept the same through all the time periods but the requirements for demonstration and uncertainty control are defined in a realistic manner. In some national regulations this has been reflected by defining the safety or compliance criteria for different time periods in a way that allows for the growing uncertainty.

In case our capacity to control the harmful effects (e.g. doses) in the future is insufficient, the pragmatic policy of regulations could be based on choosing the best alternative among the alternatives available. However, the concept of Best Available Technology (BAT) may also lead to excessive requirements if applied in the absolute sense. Modifications of the BAT, e.g. BATNEEC (BAT Not Entailing Excessive Costs), are needed to make it a reasonable concept in regulations.

The principle of intergenerational justice also arises in the context of the principle related to the burden left for future generations. It was pointed out by many speakers that the nuclear waste management activities necessarily involve future generations (for technical reasons) and the principle needs interpretation. It is most often related to the idea of avoiding unnecessary delays in waste management operations, but it can also be confronted with the principle of preserving the options for future generations. The latter principle would suggest refraining from irreversible actions. For reconciliation, retrievable disposal has been suggested, but sometimes retrievability may require compromises in the repository concepts or operation.

Some of the terms introduced in the regulatory language will need clarification (e.g. sustainability, BAT). However, the definitions developed should recognise the fact that some of terms (like “safety”) do already have meanings in the everyday language, and the terms should not unnecessarily divert from these obvious meanings.

Implications for the regulator?

Various international attempts have been and are being made to harmonise the nuclear waste regulations and regulatory practices worldwide. It has been claimed that the differences in criteria among countries constitute a difficulty for repository proposals to gain public acceptance. However, most of the speakers in this session took a cautious stance to these efforts. It was generally accepted that some level of harmonisation is welcome (e.g. for the reasons stated) but it was also brought out that the different national cultures and contexts are important and should be reflected in the regulations. Instead of harmonisation, the regulators should seek for consistency. It was noted that this was very much the idea behind the present LTSC work as well.

It was also pointed out that the stakeholder discussion – in which the implementers have now been engaged in many countries – should also be extended to the regulatory area. The regulations should be understood and accepted by the various stakeholder groups and the public. In this respect the interaction could also be two-way: not just public education but also listening to the public by the regulators.

Finally, some of the presentations of the session clearly brought out one concern: moving regulatory standards. The implementation of nuclear waste management is a long-term effort that hardly succeeds without reasonable level of stability in the regulatory standards and practices.

SESSION 3: CONNECTING HIGH-LEVEL PRINCIPLES AND OBJECTIVES WITH PRACTICAL COMPLIANCE CRITERIA

Patrick O'Sullivan
Netherlands

Session 3 of the workshop addressed three interconnected themes:

- RP criteria at extremely long times: dose, risk and/or other indicators.
- Optimisation: criteria for BAT.
- The long term and treatment of uncertainties.

Radiation Protection (RP) criteria at extremely long times: dose, risk and/or other indicators

It is evident that setting appropriate radiation protection for geological disposal facilities requires consideration of two aspects:

1. defining an acceptable level of risk; and
2. establishing what constitutes reasonable assurance of compliance with the criteria.

As regards (1), different approaches have been used internationally to set the basis for RP criteria, such as:

- a basic premise that future human beings should not receive doses from normal repository evolution that are greater than those allowed today, therefore dose constraint of 0.3 mSv/a (or less), which is broadly equivalent to a risk constraint of 10^{-5} per year;
- variability of natural background radiation – leading to a dose criterion of , say, 0.1 mSv/y; and
- tolerability of risk (UK): concluded that a risk of 10^{-6} per year is broadly acceptable to society.

In addition to numerical constraints, based on individual dose or risk, the principle of optimisation of protection is also generally applied as a complementary requirement, following the long-established recommendations of the International Commission for Radiation Protection (ICRP).

The meeting heard that the requirements for showing conformity with the numerical criteria may differ depending on the time frame in question, e.g. in Sweden:

- 0 to 1 000 years: Performance Assessment is based on today's biosphere **plus** optimisation/BAT;
- 0 to 100 000 years: PA based on illustrative scenarios for climate and biosphere (with complementary safety indicators) **plus** optimisation/BAT;
- 100 000 to 1 000 000 years: application of BAT **plus** simplified risk analysis and analysis of barrier performance;
- > 1 000 000 years: comparison with alternative waste management methods.

In addition to establishing criteria based on individual dose or risk, many programmes also use complementary safety indicators such as concentration in biosphere water and flux of radionuclides from the geosphere. These tend to be particularly useful as indicators of system performance over very long time frames for a specific site, though it may be difficult to define generic reference values for comparison and to explain these to the public given that they are further removed from the primary protection goal.

In terms of radiation protection, an important difference between regulating discharges from geological disposal facilities and from operating plants is that the latter give rise to potential rather than expected discharges. ICRP applies the term *potential exposure* to events giving rise to exposures that could occur far in the future and the doses are delivered over long time periods. Performance assessment methodologies can take account of the probability of incurring a dose (and the conditional probability of death). Following this approach a risk criterion (e.g. 10^{-5}) is used instead of a dose criterion, though the usefulness of this approach is limited by the extent that the likelihood of low probability events can be forecast. It should be noted that some countries, e.g. Sweden, require that a probability assessment is accompanied by illustrative deterministic calculations to avoid possible risk dilution.

Different views were expressed on how much harmonisation (e.g. of criteria, limits) is needed. It was noteworthy that, since the NEA Córdoba seminar[1] in 1995, no new major issues had been identified. Since then, a large number of recommendations and guidance documents, including the Joint Convention, have emerged. This, in itself, is indicative of a degree of harmonisation. More clarity is needed on why further harmonisation is needed, and it should be borne in mind that the European Commission's "Nuclear Package" of nuclear safety and radioactive waste directives (2003-2004) proved impossible to implement. Given the views expressed at the workshop, the main current need seems to be to learn from the differences in national systems, against a "common" background of understanding. Given the transboundary aspects of geological disposal, the level of safety provided should not depend on differences in national numerical criteria.

Optimisation

According to the ICRP principle of optimisation, the level of protection provided should be the best under the available circumstances, i.e. the margin of good over harm should be maximised. This requirement is complementary to the principle of dose limitation (the dose/risk standard). There has been a gradual evolution of ICRP's position on what this principle means in terms of geological disposal, with current advice focusing on the use of sound engineering principles and experience (ICRP). In the Swedish case study presented, optimisation is seen as a tool to minimise risk, based on results of risk calculations.

Closely associated to the principle of optimisation is the principle of using best available techniques (BAT), which relates to the minimisation of radioactive emissions and originates from the system of integrated pollution control. BAT includes management techniques and includes idea of practicability (not entailing excessive cost). In the Swedish case study, the main focus was on the barrier functions provided to "hinder, reduce and delay releases from engineered and geological barriers".

As regards the practical application of optimisation and/or BAT, it is evident that an iterative approach to developing safety case facilitates structured approach to optimisation. Although the two principles have different origins, there is likely to be little difference in their practical application, especially where the main focus is on practical aspects relating to barrier performance. Views

1. Regulating the Long-term Safety of Radioactive Waste Disposal, Córdoba, Spain, 1997.

expressed at the meeting suggested a possible need for regulatory guidance on the application of these principles, but warned against developing sub-system criteria (on the basis that the regulator cannot foresee precisely what will arise in the proponent's safety case).

The long term and treatment of uncertainties

Certain key requirements are evident from the presentations and discussions:

- Uncertainties should be described and handled in a consistent and structured manner.
- Uncertainties can be evaluated by sensitivity analysis (barrier performance, consequences to human health and environment.
- Hierarchy of approaches to dealing with uncertainty, i.e. eliminate if possible, account for in the design, reduce or constrain, circumvent, accept residual uncertainty and deal with in the safety case.

The following general points emerged from the discussions:

- It is the responsibility of the applicant to develop a full safety case, which may include a statement on the ultimate fate of the repository.
- It is necessary to demonstrate that the safety case is based on a structured analysis, so that there is flexibility to make changes (e.g. in the event that mistakes are discovered).
- The safety case makes an important contribution to public confidence in the safety of a proposed geological disposal facility.

Certain limitations in the use of probabilistic assessments were emphasised, e.g. the use of conservative assumptions may obscure differences between alternative options (e.g. between alternative sites).

Overall conclusions from Session 3

An important aspect to be borne in mind is that the greater the focus on optimisation/BAT – rather than compliance with the dose/risk constraint over long time frames – the less important are the variations in the criteria used by different countries.

It should also be emphasised that an important function of the safety case is to demonstrate a good understanding of the proposed disposal system, with a sufficient level of confidence in the safety case assumptions.

The prevailing view as regards the issue of harmonisation is that it is important to have agreement on overarching objectives, but flexibility in implementation (national criteria, etc.) is still necessary.

Finally, the technical community needs to take account of the perspectives of stakeholders, and an assessment of confidence in the level of safety provided needs to address needs of stakeholders (e.g. the ultimate fate of repository may need to be described as this is one of the issues in which stakeholders are frequently interested).

Appendix 4

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Regulating the Long-term Safety of Geological Disposal of Radioactive Waste: Practical Issues and Challenges

Regulating the long-term safety of geological disposal of radioactive waste is a key part of making progress on the radioactive waste management issue. A survey of member countries has shown that differences exist both in the protection criteria being applied and in the methods for demonstrating compliance, reflecting historical and cultural differences between countries which in turn result in a diversity of decision-making approaches and frameworks. At the same time, however, these differences in criteria are unlikely to result in significant differences in long-term protection, as all the standards being proposed are well below levels at which actual effects of radiological exposure can be observed and a range of complementary requirements is foreseen.

In order to enable experts from a wide range of backgrounds to debate the various aspects of these findings, the NEA organised an international workshop in November 2006 in Paris, France. Discussions focused on diversity in regulatory processes; the basis and tools for assuring long-term protection; ethical responsibilities of one generation to later generations and how these can be discharged; and adapting regulatory processes to the long time frames involved in implementing geological disposal. These proceedings include a summary of the viewpoints expressed as well as the 22 papers presented at the workshop.

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